A Database of LLNL Sensor Technologies

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THIS DOCUMENT CONTAINS A DATABASE, FOLLOWED BY ONE VUGRAPH, OR EXECUTIVE SUMMARY FOR MOST OF THE SENSOR TECHNOLOGIES LISTED *(NOTE: A one page vugraph or summary is not available for every sensor listed in the database).*

LLNL Sensor and Sensor System Listing

	Project Name	Technology Maturity	Intellectual Property	R&D Status	Point of Contact	Principal Investigator	Technology Description
Acoustic Sensors							
A1	Ultrasonic Tomography	Late stage development	Multiple patents LLNL+	Prior WFO project	R. Twogood	J. Candy	3-D ultrasonic diffraction tomography system for breast cancer detection and other applications.
A2	Acoustic detection of flaws via timereversal	Preliminary R&D done	Patent filed	LDRD Project completed	J. Candy	J. Candy	Uses the dominant-scatterer focusing property of time reversal to iteratively detect the dominant flaws in materials under insonification.
A3	Acoustic Sensor	Prototype developed needs work in user interface	Know how and copyright of software	No longer Active	K. O'Brien	D. Chinn and P. Souza	Sensor that is non-invasive and extremely accurate for measurement of solution concentration and crystal size. Based on velocity of wave through solution. Used to measure KDP crystal growth.
A5	High Energy, Low Frequency Ultrasonic Transducer	Prototype demonstrated	Patent		K. O'Brien	Al Brown	Wide band-width, ultrasonic transducer to generate non-dispersive, extensional, pulsed acoustic waves into concrete reinforced rods and tendons.
Bio Sensors							
B1	Single-Fluorescent Molecule Control Microscopy	Preliminary R&D done, lab demo	TBD	LDRD Project completed	C. Darrow	C. Darrow	Detects fluorescent molecules which have been chemically attached to antibodies.
B2	Direct Detection of Biological Activity	Preliminary R&D done	TBD	LDRD Project completed. CBST funding.	T. Huser	T. Huser	Detects biological agents based on the ability of two dye-labeled molecules to transfer energy when, and only when, in close proximity.
B3	Bio-Assays Using Liquid-Based Detection Arrays	Benchtop feasibility; student will develop prototype and do testing at UCD	ROIs filed	LDRD Project completed. CBST funding now.	F. Chuang	S. Visuri	Rapid, flexible, high-throughput, multi-plex capable biological assay system using liquid array optical encoding of small diameter leads. aPDS Project. Steve V. will have student doing portable version. Point-of-Care applications, portable focus. No need for flow cytometer, sampling fluids, Luminex technology, different colors, with antobodies.Antibody / antigen/ fluor. tag. Capture of iflter, 2d image of filter, look at color changes and intensity. Research is pre-treatment, sample handling.
B4	Protein chip based sensor	Concept stage	None yet	CBST and SEGRF	R. Rao	S. Visuri	Rupa Rao at UCD submitting DoD grant. LLNL strength is in instrumentation. Use commercially available biomarkers. Lower density than commercial protein chips. Emphasis on POC sample pre and detection.
B5	BioBriefcase	Development Stage (2 yrs. to demo)	ROIs filed	DOE / DHS	J. Dzenitis	S. Visuri	No beads (as compared to APDS). Use capillary electrophoresis. Microfluidic approach to sample prep. Smaller size, less reagents, same speed, poetntail better specificity and sensitivity. Set for sampling large volumes of air. Sample prep, immunoassays, PCR on board. First reponsder focus, no need for microbiologist.

LEGEND
Active and looking for funding
Licensed to industry partner
Not active, no potential for interactions or funding
Active, but not ready to be presented for funding

	Project Name	Technology Maturity	Intellectual Property	R&D Status	Point of Contact	Principal Investigator	Technology Description
				Bio Sensors			
B6	MIDAS	Feasibility Stage	ROIs filed?	LDRD	C. Carter	C. Carter	Chemical sensors on end of fiber optics. Periodontal disease (look for enzymes in mouth), diagnosing stage of stroke, pH and some enyzme measurements
B7	APDS	Field tested unit	YES	Licensed to company	J. Dzenitis	J. Dzenitis	License with Partner did NOT go through
B8	DNA Pillar based sensor	Feasibility Stage	IP owned by Industry Partner	CRADA with company, some tech based	K. Ness	K. Ness	High aspect ratio (40:1) Si based pillars that can be used to capture DNA. Can then back-flush to remove captured DNA for subsequent analysis.
B9	Carbon-nanotube based AFM				J. De Yoreo	J. De Yoreo	Carbon-based nanotubes used as AFW probes in fluids for in situ imaging and identification of viruses and for single-molecule investigations of crystallization.
B10	Water sensor	Feasibility Stage	Not yet	Tech Based funding	K. O'Brien	R. Miles	Use of Dielectrophoresis to detect pathogens in potable water. Used downstream of Ultrafiltration membranes in the production of potable water.
B11	Multiplexed Bioassays Portable Instrument	Feasibility Stage	ROI submitted	ER funding for 3 years		P. Krulevitch / Steve V.	Working with Nanobarcodes from Nanoplex. LLNL building system, Nanoplex supplying the particles.
B12	Urea Biosensor for Hemodialysis Monitoring	Prototype?	Patent		K. O'Brien	B. Glass	Detect and quantify urea influids resulting from hemodialysis. Measures pH change due to enzyme catalyzed hydrolysis of urea.
B13	Implantable Medical Sensor	Rough protyping done, additional R&D would need to be done	Patent	No funding at this time, no on-going work, some inventors gone	K. O'Brien	C. Darrow, J. Satcher, Steve Lane, Abe Lee, Amy Wang	Biocompatible polymer expands in response to a specific analyte. Expansion is correlated with concentration of analyte. MEMS based sensor can be used to measure resulting pressure generated by expansion of biopolymer.
				Chemical Sensors			
C1	Optical Chemical Sensor	Early stage development	None	Former project	R. Kiefer	B. Anderson	Simple reversible fiber-optic chemical sensor
				EM Sensors			
E1	Contact Stress sensor (Electrical)	Prototypes exist.	Patent appl.	DNT and Tech base	M. Pocha	T. Lavietes / J. Kotovsky	Linearity and repeatability is advantage over commercial systems. Most commercial systems are polymer based, act non-linear and show hysteresis. Silicon based system. Size advantage, constructed using MEMS. Cantilever beam type system like optical one, but different other than this aspect.
E2	Electrical Resistance Tomography (ERT)	Mature-ready for licensing, prototype system developed	Patent(s) some IP encumbrance	Existing and continuing DOE funded project	R. Kiefer	B. Daily	Geophysical subsurface imaging process for environmental remediation, oil reservoir management and various underground monitoring applications.
				Gas Sensors			
G1	MEMS GC	Mature-ready for licensing, prototype GC in use	Patents, know how & drawings	Existing and continuing DOE funded project	R. Kiefer	C. Yu	Hand-held GC based on MEMS manufacturing techniques

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	Project Name	Technology Maturity	Intellectual Property	R&D Status	Point of Contact	Principal Investigator	Technology Description
Gas Sensors							
G2	Handheld GC	Early stage development	ROIs in process of filing	DOE funding	R. Miles	R. Miles	Different from previous approach. Utilizes standard columns (as compared to MEMS columns). More COTS components than before.
G3	Portable GCMS	Mature		Existing and continuing DOE funded project	C. Pruneda	B. Andresen	Field-portable GC-MS system for forensic and other field applications
G4	Hydrocarbon Sensor	Prototype demonstrated, needs packaging improvements	Patents	Funded through US automotive CRADA, encumbered	K. O'Brien	Q. Pham, B. Glass	Applications for the on-board monitoring of automotive exhaust gases to evaluate the performance of catalytic converters. Proton conducting electrolyte sandwiched between two electrodes.
G5	NOx Sensor	Prototype FY02 or FY03, needs more work	ROIs filed	Funded through CIDI Engine program, working with Ford.	K. O'Brien	B. Glass	
Nuclear Sensors							
N1	Gamma Ray Detector	Proof-of-Concept complete; lab instrument	TBD	LDRD Project completed	K. Ziock	K. Ziock	Full-Volume-Imaging Gamma Ray detector. Electrons in detector record depolsion of energy by gamma rays from imaged source.
N2	Nanotubes for WMD Detectors	Basic R&D	Patent submitted	LDRD Project completed	B. Andresen	B. Andresen	Carbon nanotubes possess properties that may admit detection of target compounds in air from weapons of mass destruction.
Optical Sensors							
O1	Profilometer	Medium stage technology, proof of concept demo complete, no prototype	Patent(s)	Former project, not currently funded	M. LaChapell	M. Bowers	Non-contact, laser based, highly accurate measurement system. Similar to commercial systems, commercial optical systems do exist.
O3	Speckle reduction for lidar		TBD	LDRD Project completed	M. Bowers	M. Bowers	High-fidelity optical-phase conjugator added to lidar system reduces speckle in lidar measurements.
O4	Optically Polarized NMR		TBD	LDRD Underway	S. Hayes	S. Hayes	Laser light used to excite spin-polarized electron-hole pairs to greatly enhance nuclear magnetic imaging.
O5	Advanced Imaging Catheter		Patents filed & issued	LDRD Project completed	P. Krulevitch	P. Krulevitch	Compact catheter using a variety of materials and techniques to offer imaging and active control of catheter to enhance physician's navigational ability.
O6	Autonomous On-Orbin Docking	Lab Prototype	TBD	LDRD Project completed. Teaming with Lockheed Martin and approaching DoD for funding.	L. Ng	L. Ng	Vision-based object tracking system using stereo-ranging and laser-ranging system to support autonomous docking functions.
O7	MEMS arrays for prosthetic retina	Beginning CRADA, no prototypes yet	Patent	DARPA funded, multi-lab with private industry	K. O'Brien	P. Krulevitch	Flexible sensor array that can be implanted in the retina and constructed from PDMS. Used to stimulate nerve tissue and communicates via RF.

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Optical Sensors							
O8	Accelerometer (optical Suite of sensors)	Some early stage field staging complete	Patent appl.	DNT funded	M. Pocha	T. Lavietes / Swierkowski	Advantage of being optical readout: no wires, use fiber optics. No electrical connection. Comparable size, temp range, etc as to MEMS based accelerometers. Interest in the area of aircraft, use in explosive environments.
O9	Contact Stress sensor (Optical)	Concept stage	Patent appl.	DNT and Tech base	M. Pocha	T. Lavietes / J. Kotovsky	Linearity and repeatability is advantage over commercial systems. Most commercial systems are polymer based, act non-linear and show hysteresis. Silicon based system.
O10	Linear Displacement Sensor	Concept stage	Patent appl.	DNT funded	M. Pocha	T. Lavietes / B. Wood	Size and geometry advantage over commercial systems.
O11	Shock sensor	Prototype Stage	know how	DNT funded	M. Pocha	T. Lavietes / B. Wood	Improvement on LANL system. Still under development. Trigger pulse output, e.g. can be used to trigger other measurements.
O12	Miniature Fabry-Perot Data Processor	Prototype exists	Maybe just know-how	DNT and Tech base	M Pocha	T. Lavietes / M. Pocha / C. McConaghy	Advantage over existing systems is smaller size and less power required. Less functionality than commercial systems, I.e. less readouts available.
O13	Gap gauge	Prototype exists, preparing for field tests	Patent appl.	DNT funded	M. Pocha	T. Lavietes / B. Wood	1 mm or less gap sizes are being measured. Measuring gaps when bringing together two parts. Need something that would slip into gap. Replaces use of linear displacement sensor. Scissors jack with support structure. Package itself is 2 mm in height when it is UNFLEXED.
O14	High voltage photovoltaic array	Prototype Stage	know how	DNT and Tech base	M. Pocha	G. Cooper / G. James	Goal is to achieve kV levels of voltage, nothing exists. Photocells in series, generate high voltage locally with ONLY optical input. NO high voltage ELECTRICAL connections coming into unit.
O15	Optochemical Sensors	Prototypes developed, on-going work for glucose detection	Patents	Funded by MiniMed for glucose, need funding for other applications	K. O'Brien	S. Lane, T. Peyser	Non-invasive chemical sensor for quantitatively monitoring aging of material or amount of chemical species present. Based on Photoinduced Electron Transfer (PET) which gives “switchable” fluorescent sensors.
O16	Light Lock Optical Security System	Prototype, team broken up	Know how	No longer funded, team members gone or on other projects	K. O'Brien	B. Stoddard, R. Clough, R. Main, K. Hagans	Lock is passive, key emits laser pulse. Converted to digital signal that results in mechanical action to open lock.
RF Sensors							
R1	Wireless seismic sensor network	Med. stage, small sensor array demo'd	Software	Existing and continuing DOE funded project	D. McCallen	B. Henderer	Self-configuring, self-healing wireless sensor network
R2	Asset Protection System	Mature-currently military/gov't only	TBD		S. Azevedo	S. Azevedo	Battery operated radar sensor for intrusion detection; potential for air-drop or hand emplacement.
R3	Bunker/Cave Monitoring Network	Medium stage dev.; prototype in prep.	TBD	Prior LLNL funding, current DoD	S. Azevedo	S. Azevedo	Battery operated sensor network with commercial communication links.
R4	Electronic Tripwire	Mature-military/gov't only	TBD	Prior DoD funding	S. Azevedo	S. Azevedo	Battery operated sensor suitable for initiation device or transponder.

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RF Sensors							
R5	Flashlight Sensor	Mature-military/gov't only	TBD	Prior LLNL and DoD funding	S. Azevedo	S. Azevedo	Battery operated radar sensor for personnel detection or warning device
R6	Human Presence Imager		TBD		S. Azevedo	S. Azevedo	
R7	Perimeter Sensor		TBD		S. Azevedo	S. Azevedo	
R8	Portal Sensor	Medium stage development	TBD	Prior LLNL funding	S. Azevedo	S. Azevedo	Medium resolution RF imager for personnel walking through portal.
R9	HERMES	Late stage development	Patents & know how	Existing and continuing DOT support	R. Twogood	J. Hernandez	3-D RF imaging system for bridge deck inspection.
R10	Ultra Wideband Comms	Medium stage development	Know how	Current LDRD	R. Twogood	F. Dowla	
R11	Radar subsurface Imaging	Medium stage	TBD	LDRD completed; no current funding	S. Azevedo	S. Azevedo	Ground-penetrating radar and imaging system for 3-D reconstruction of images of emplaced landmines.
Misc. Sensors							
M1	Smart Camera	Mature-ready for licensing, prototype undergoing alpha and beta testing	Patents & software	Existing and continuing DOE funded project	R. Kiefer	D. Coffland	Digital video surveillance system
M2	MEMS Fuel Cells	Med. stage technology, proof of concept demo complete, no prototype	Patents & know how	Existing and continuing DARPA, LDRD funded project, industrial funding	K. O'Brien	J. Morse	Proton exchange membrane (PEM) and solid oxide (SOFC) MEMS-based fuel cells are licensed and being developed for industry partners.
M3	Six degree of freedom sensor	Mature-ready for licensing, prototype developed	Patent(s)	Former project	B. Grant (IPAC)	C. Vann	Low cost, non-contact, laser based sensor which accurately measures its relative position to an object in all six degrees of freedom
M4	Femtoscope	Proof-of-Concept lab demo	Patent appl.	LDRD Project completed	M. Lowry	Bennett/Lowry; B. Kolner, UCD	Time microscope using temporal imaging. Proof-of-concept imaged 100 fs pulse with >100X time magnification.
M5	TOF-MS		TBD		K. Langry	K. Langry	
M6	Low-charge State Accelerator Mass Spectrometer	Prototype lab instrument	TBD	LDRD Project completed	J. Vogel	J. Vogel	Demonstration of roam-sized AMS system for biological research.
M7	MEMS Accelerometer	Prototype developed, needs more work on wireless interface	Patent	PIs have left LLNL. No longer funded	K. O'Brien	A. Lee / B. J. Simon	Accelerometer that exhibits low frequency (< 50 Hz), high sensitivity (microgauss), and uses minimal power.
M8	Magnetohydro-dynamic Pump and Sensor	Prototypes developed, needs addition R&D	Patents	Robin Miles and Soni looking for NIH funding	K. O'Brien	R. Miles (formerly A. Lee)	MEMS based pump with no moving parts, minimal dead volume, and low power requirements. Uses Lorentz force to propel fluid.
M9	Polymer Integration Platform	Proof-of-Concept lab demo, prototype end of year	Patent appl (8)	Funding from NA22 (NAI)		P. Krulevitch / C. Davidson	Integrates optics, microfluidics, sensors, electronics. Use of PDMS, acts like PC board. Sticky so can stick to surfaces. Can also metalize system.
M10	Tilt Meter					S. Hunter	R&D 100 winner
M11	Plume Prediction	Prototype	know how	Featured to OHS	S. Kulkarni		Palm Pilot equipped with gaussian program to predict path of plumes. Designed for first responders.

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Acoustic Sensors

A1

3-D Ultrasonic Tomography System

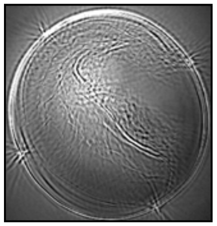
What it does

- 3-Dimensional imaging system using ultrasonic tomography.
- Initial application—breast cancer detection.
- Provides quantitative ultrasonic transmission data, i.e, gives new information to physician.
- Transmission imaging of a 3-D volume.

Accomplishments/Status

- Ultrasonic scanner built at LLNL.
- Advanced multi-dimensional diffraction tomographic image reconstructions demonstrated.
- More than a dozen patents submitted.
- Proof-of-concept completed with impressive results.

Technology



- High resolution UT scanning hardware and systems.
- Sophisticated imaging algorithms:
  - —Both transmission and reflection.
  - —Full aperture tomography and diffraction tomography codes implemented and tested.

Business Model/Opportunity

- Successful proof-of-concept has positioned technology for medical commercialization.
- KCI has spun-off a new start-up company and is seeking venture capital and/or corporate collaborations for breast cancer detection.
- Technology (scanner, algorithms) available for broader set of UT imaging applications.
- Sophisticated imaging algorithms:
  - — Both transmission and reflection.
  - — Full aperture tomography and diffraction tomography codes implemented and tested.

Dynamic focusing of acoustic energy for nondestructive evaluation

J. V. Candy, J. G. Berryman, D. H. Chambers, R. D. Huber, K. A. Fisher, A. L. Meyer, G. H. Thomas

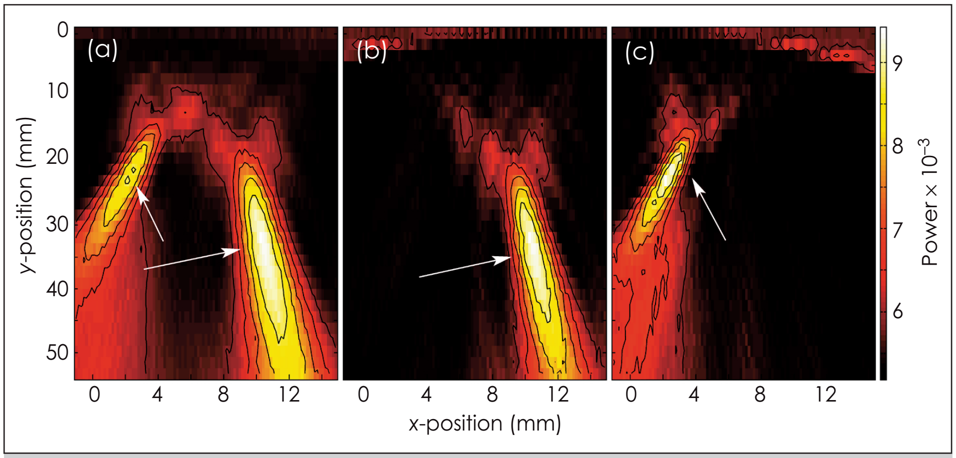
Our goal in this project was to research and develop a nondestructive evaluation (NDE) technique for dynamically focusing acoustical energy to both detect and characterize flaws in parts undergoing ultrasonic testing. Our approach incorporated detailed simulations, algorithm development, hardware, proof-of-principle experiments, and the design and construction of a prototype flaw-detection/localization/imaging system.

The dynamic-focusing method that we have designed uses time-reversal (T/R)—a technique for focusing on a reflective target or mass through a homogeneous or inhomogeneous medium excited by a broadband source. Our T/R processor detects flaws (or scatterers) by utilizing its primary attribute—the ability to iteratively focus on the strongest flaw. A T/R processor simply receives the multichannel time series radiated from the region under investigation, collects the array data, digitizes, time-reverses the sensor-array signals, and then re-transmits the signals back through the medium to focus. A patent using the T/R decomposition approach to identify flaws in parts for NDE is pending.

Our T/R technique has application to many areas of high interest to the Laboratory. These include (1) detecting flaws in lenses for laser-based optics and also in component parts of weapons systems as part of the Stockpile Stewardship Program; (2) developing revolutionary, noninvasive medical treatments; (3) designing new methods for secure communications; and (4) designing seismic applications such as locating underground structures.

During FY2001, we expanded the scope of the project to include the initiation of collaborations with researchers at both Stanford and Iowa State Universities to investigate T/R processing techniques for random media and multimode scattering structures, respectively. We also developed—conceptually and theoretically—an approach to treating tissue masses using T/R focusing. Finally, we completed a prototype T/R system and performed a wide variety of proof-of-principle, ultrasonic NDE experiments. These included flaw detection and localization in aluminum, laser optics, and a layered composite part. As one of the experiments, we selectively focused on the strongest flaw in an aluminum part and then on the weakest flaw (see Figure), thereby demonstrating the focusing capability using T/R processing. The idea was to compare the iterative focusing capability of the T/R processor [Figs. (b,c)] to an eigen-decomposition approach using the T/R operator directly in the part [Fig. (a)] The results demonstrate that both approaches are capable of focusing ultrasonic energy on the strongest flaw—very important to detecting flaws in high-power laser optics.

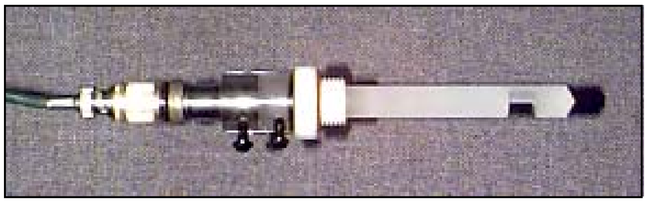
The results of our work have appeared or will soon appear in a number of refereed journal articles.



Selective focusing using the time-reversal prototype system on an aluminum part with two flaws: (a) raw image (unfocused array illumination); and array source localization on (b) the strongest flaw, and on (c) the weakest flaw.

Acoustic Sensors

What it does

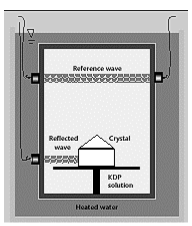


- Non-invasive and extremely accurate measurement of solution concentration and crystal size.
- Sensors can be submerged in solution or placed on the outside of vessel.

Accomplishments/Status

- Able to measure growth of Potassium dihydrogen phosphate crystals that are 0.4 m^2 in size to ± 0.1 mm. Over 10x improvement in accuracy over existing means.
- Does not require visual measurement during crystal growth.

Technology



- Acoustic velocity is directly proportional to density
- Acoustic velocity varies with temperature and solution concentration.
- Velocity of wave through solution is related to concentration.
- Velocity of reference vs. reflected wave enables calculation of crystal size.

Business Model/Opportunity

- Applications for Industrial Automation, especially process control.
- Original work performed with DOE funds for National Ignition Facility.
- Looking for R&D partners with expertise in industrial automation and process control to co-develop more user friendly operator interface.

Bio Sensors

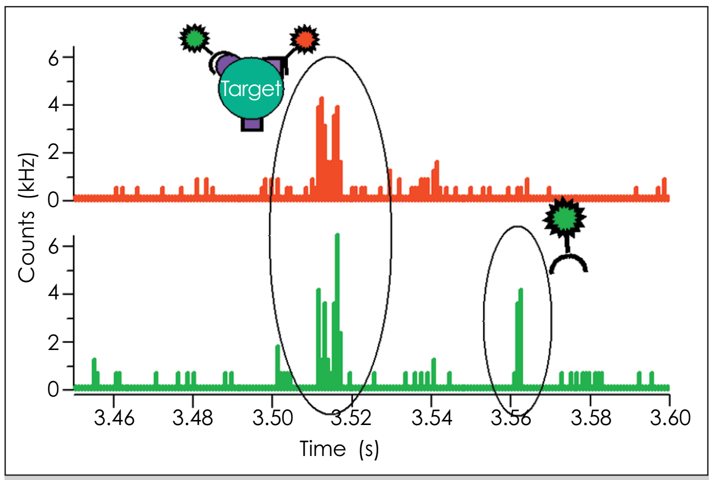
Single-fluorescent-molecule confocal microscopy: A new tool for molecular biology research and biosensor development

S. M. Lane, C. W. Hollars, T. R. Huser, R. L. Balhorn

The ability to detect and identify a single molecule represents the ultimate limit in detection sensitivity. Because of advancements in microscopic techniques over the past decade, this capability is being used with fluorescent molecules for a variety of applications. Our goal is to exploit this inherent sensitivity of single-molecule detection (SMD) in the development of ultrasensitive immunoassays for use in biological, medical, and national security applications. This achievement would improve sensitivity by a factor of 1000 or more over that of current, state-of-the-art, nonamplified analysis of biological molecules, which is typically limited to nanomolar detection limits.

During FY2000, we had successfully used a dual-label approach for the single-molecule analysis of a protein target molecule at nanomolar levels. The scheme used three antibodies to the target, two tagged with spectrally distinct fluorophores. This approach drastically reduces the occurrence of false-positive detected events because it requires the simultaneous signal detection of the two fluorophores at the same place on the sample to within the resolution of the microscope (about 250 nm). In this analysis, the labeled target is captured using the third antibody, which is attached to the surface of a glass microscope slide using silanization methods. We were unable to realize the ultimate sensitivity of this analysis because of the nonspecific attachment of the labeled antibodies to the surface of the slide—probably due to incomplete silanization of the surface, which provided areas of exposed glass to which the proteins and antibodies readily and nonspecifically attach.

In FY2001, our experimental effort was focused on developing a more suitable silanized surface. We investigated both the nonspecific attachment of fluorescently labeled antibodies on glass surfaces prepared with numerous silane species and silanization protocols. Where these efforts produced a reduction in nonspecific binding, we were able to demonstrate improved sensitivity at ultralow target concentrations.



Two-color fluorescence intensity traces of a freely diffusing target/labeled-antibody solution. The coincident burst at about 3.51 s indicates the detection of a target molecule, which is distinguished from the detection of a lone antibody at about 3.56 s.

By probing freely diffusing target molecules, we circumvented the nonspecific binding that limits the surface-capture method just described. Fluorescent molecules are detected through observation of short, intense photon bursts when the fluorescent molecules diffuse through the focal spot, as the Figure shows. Coincident emission of a photon burst in both emission channels indicates a doubly labeled target molecule; unbound antibodies or targets with one attached antibody are single-channel events. Because the target is detected in solution, no surfaces are involved, and limitations caused by nonspecific binding have been removed. However, this approach is limited by a small detection volume (1 fl). Thus, at femtomolar concentrations, detecting a sufficient number of positive events to perform a realistic assay would require impractical lengths of time.

On the basis of these results, future efforts in this area will focus on developing a single-molecule assay that utilizes a microchannel with dimensions on the order of 0.5 × 100 × 100 mm. This device would have 10^3 to 10^4 times greater throughput than the previously discussed 1-D approach. The development of a practical flow channel of these dimensions and the use of a video-rate, charge-coupled device (CCD) camera to image the fluorescent molecules in the flow field will dramatically increase the detection volume, and thus reduce the analysis time of ultralow concentrations to minutes or possibly seconds.

A New, Ultraspecific Optical Method for Sensing Biological Agents: Direct Detection of Biological Activity

J. H. Satcher, Jr., R. L. Balhorn, C. B. Darrow, D. R. Cary, J. P. Bearinger

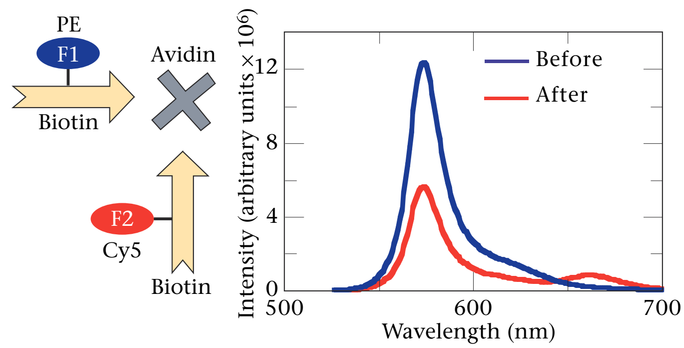
Both the public health and defense sectors have an important need for ultrasensitive biosensors and assays that are capable of rapidly detecting dangerous biological agents—viruses, bacteria, parasites, and toxins. The bioagent-detection technologies available today are limited by time-consuming or multistep sample processing and the inability to identify specific bioagents. We are investigating a detection method that (1) requires little or no processing, (2) significantly increases sensitivity, and (3) quickly reports the presence of infectious airborne, waterborne, or blood-borne organisms or toxin-producing micro-organisms.

Our detection scheme is based on the ability of two dye-labeled molecules to transfer energy when, and only when, they are in close proximity, which then can be detected by fluorescence spectroscopy. By eliminating nonspecific binding, our detection scheme would distinguish between live and inactive viral particles—something no current detection method is capable of doing—and would greatly improve the performance of existing sensors.

In work begun in FY1999 and completed in FY2000, we investigated a protein-coat portion of the HIV virus to demonstrate the effectiveness of our method. We chose the HIV virus because it has two protein receptors that bind specific sites on the virus's surface protein coat. Once these sites on the viral surface are occupied, the HIV virus changes its protein structure to physically collocate the two protein receptors.

First, we established energy transfer with two dyes (Coumarin and Nile Blue) in solution. To demonstrate that energy transfer can indicate specific interactions between proteins, we labeled hairpin DNA on opposite ends with two dyes (Cy5 and TMR). When the ends of the DNA strand interacted (through hydrogen-bonding forces), we observed energy transfer.

Next, to demonstrate that energy transfer can indicate interaction between a protein and a small molecule, we labeled two different molecules with different dyes (biotin with Cy5 and avidin with PE). When the two molecules were mixed, energy transfer took place. By labeling the same donor with different dyes (biotin with Cy5, biotin with PE, and avidin unlabeled), we also demonstrated that energy transfer could indicate that a large receptor molecule was bringing two small donor molecules into close proximity. Energy transfer occurred when the dyes were mixed (see Fig.). These experiments established that our technique for using energy transfer to detect donor–acceptor interactions could distinguish between live and inactive viral particles, as we propose to do for HIV detection.



The emission spectrum of the two labeled biotins using the excitation band (494 nm) of the PE label. In the* before *spectrum, only the PE emission band is seen because the Cy5 label is not excited and no energy transfer occurs. In the* after *spectrum, with avidin added, the two biotins are collocated, energy transfer occurs, and the emission band of the Cy5 label is detected.

Our work on larger molecules with complementary binding sites met with some success. We first demonstrated the ability of the technique when applied to larger molecules by using a large (~100+ Å, >50,000 g/mole) protein (Cd8) with two different complementary labels (Cy5 and PE). We observed energy transfer. To demonstrate that the interaction of two complementary large proteins could be indicated by energy transfer, two large proteins were labeled with different dyes (Cd4 with Cy5 and anti-Cd4 with PE).

Initial results showed large baseline and background corrections prevented easy detection of energy transfer for the larger molecules. Although manipulation of the excitation energy eliminated some of the interferences, energy transfer was detected for only one label (PE) and not the other (Cy5). Results of our attempts to resolve this discrepancy indicated that nonspecific interactions can influence intensity changes. Along with the baseline and background problems, this suggests that different dyes probably are necessary for clearer detection of energy transfer for the Cd4 and anti-Cd4 pair.

Broad-base biological assay using liquid-based detection arrays

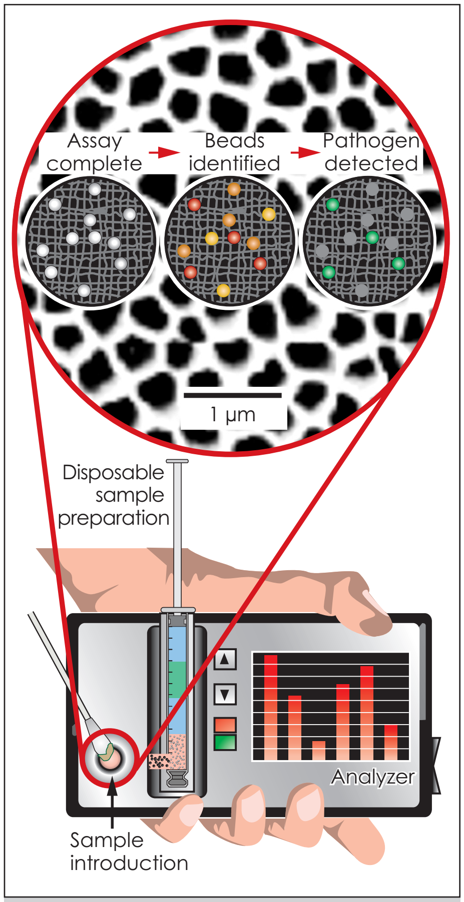
F. Milanovich, B. Colston, J. Albala, S. Visuri, K. Venkateswaran

The release of a biological agent by terrorists represents a serious threat to the safety of U.S. citizens. At present, over 50 pathogens and toxins are on various agency threat lists. Many of these pathogens have symptomatic delays of days to weeks, delays that seriously compromise effective diagnosis and treatment. This translates into two major deficiencies in our ability to counter biological terrorism: (1) the lack of any credible technology to rapidly detect and identify all the pathogens or toxins on current threat lists, and (2) the lack of a credible means to rapidly diagnose thousands of potential victims.

In this project, we have been developing a rapid, inexpensive, high-throughput, multiple target, pathogen-assay technology. The technology, which we call the Liquid Array (LA), utilizes optical encoding of small-diameter beads that serve as the templates for biological capture assays. Our goal was a detection technology capable of simultaneously identifying hundreds of different bio-agents and/or rapidly diagnosing several thousand individuals.

We pursued this research in three thrusts. In the first, we explored the fundamental interactions of the beads with proteins and nucleic acids in complex mixtures. This provided us with a complete understanding of the limits of the technology with respect to throughput and complex environment. A major spinoff of this work is in the rapidly emerging field of proteomics—the protein complement of genomics. In the second thrust, we looked at a model human-disease state to assess the application of the LA in a highly challenging, real-world medical diagnostic. Finally, we developed a novel concept that would utilize the bead assay in the simplest possible instrument format. A portable, affordable biodetection instrument would provide ease of use for emergency first responders and a point-of-care diagnostic capability for physicians.

During FY2001, we used the LA technology to further elucidate the dynamics of two different bacterial DNA-repair systems (UvrABC and RAD 51BC). Initial results confirmed the ability of these proteins to discriminate between damaged and undamaged DNA bound to individual bead sets. However, because proteins bind to each other and DNA much more weakly than antibody–antigen reactions, discrimination of individual interactions in this relatively complex environment continues to be a challenge.



A disposable apparatus for making multiplexed measurements. For imaging and analysis, reagents are loaded and serially dispensed from a multiseptum syringe onto a membrane.

In collaboration with researchers at the University of California, San Francisco (UCSF), and the California Department of Health Services (DHS), we demonstrated multiplex assays for diagnosing a cancer-inducing virus (human herpes virus 8) prevalent in AIDS victims and for determining vaccine efficacy for preventable childhood diseases (mumps, measles, rubella, and chicken pox). We validated both assays on hundreds of real serum samples against benchmarked standards, and we are preparing this research for publication in first-tier scientific journals.

Finally, we made excellent progress in the development of a portable pathogen-detection device. Minimal operator involvement is required beyond sample introduction, so that untrained personnel such as first responders can run sophisticated diagnostics onsite. We designed and constructed several disposable sample-preparation prototypes (see Figure) and were able to demonstrate that their performance was comparable to that of existing bench-top methods. In addition, we constructed a brassboard analyzer for reading the bead assays and developed, in collaboration with researchers at the University of California, Davis and DHS, a panel for screening respiratory viruses. At year's end, we were identifying potential commercial partners for transferring this technology.

Our work has resulted in a number of patents and articles in refereed journals.

Multiplexed Protein Detection System

Rupa Rao, University Of California, Davis

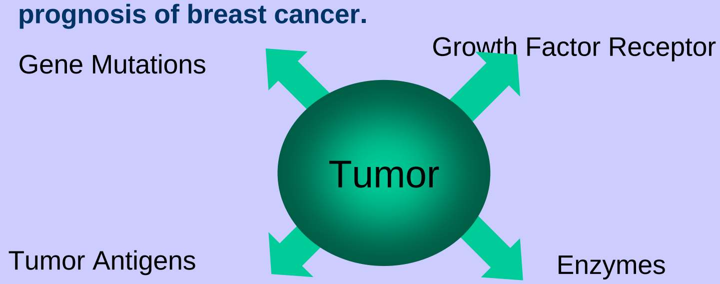
Steven Visuri, [2] Matthew A.Coleman, [2] Joanna Albala, [2] Mary T. McBride, [2] Dennis Matthews[1,2]

[1]University Of California, Davis,[2]Lawrence Livermore National Laboratory

Our goal is to design a small, automated device capable of measuring multiple serum markers in the doctor's office that will be a valuable tool for patient screening and monitoring. Initially, we will apply this technology to the diagnosis of breast cancer, a disease of multiple origins and complex signaling pathways, that will benefit from monitoring a signature panel of biomarkers.

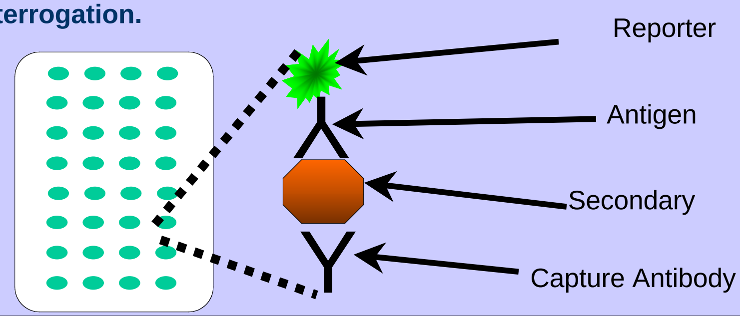
Introduction

Prior to the appearance of physical symptoms, tumors express molecular changes that can be detected by biochemical techniques, which can be used for early diagnosis and prognosis of breast cancer.



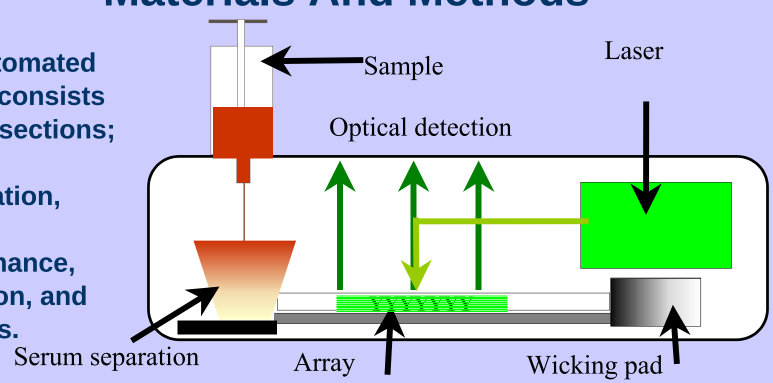
Materials And Methods

The technique consists of a performing multiplex sandwich immunoassay son a pre-spotted array, followed by optical interrogation.

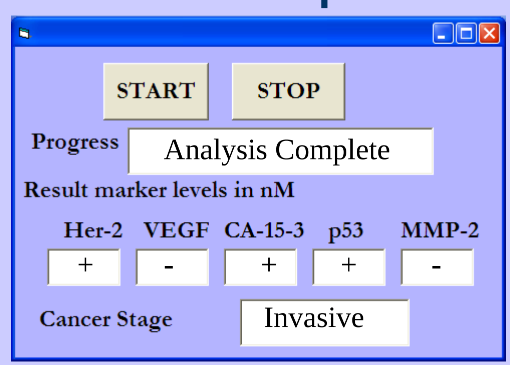


Materials And Methods

The automated device consists of four sections; sample preparation, assay performance, detection, and analysis.



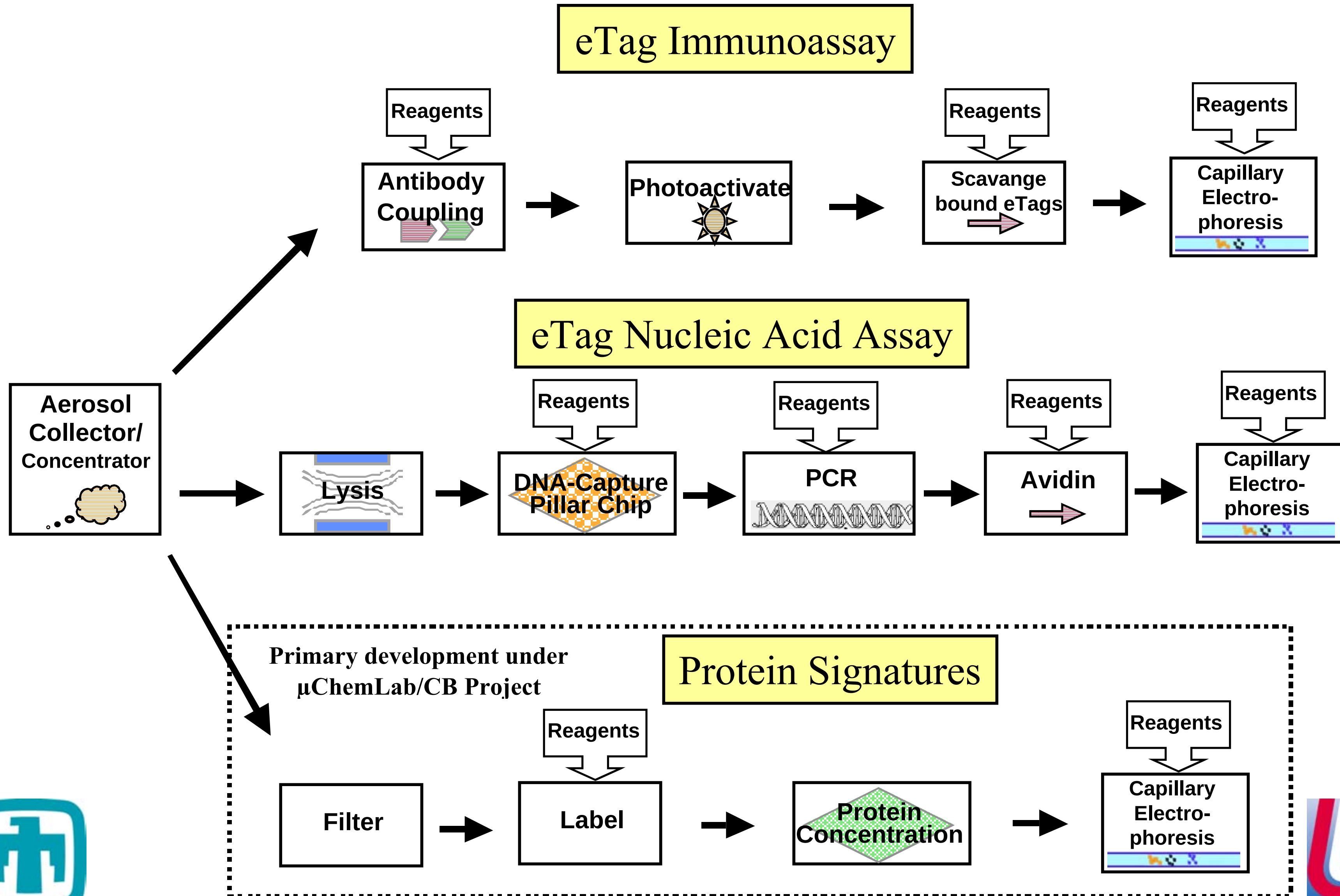
Expected Output



The biomarkers will be quantified and collectively compared with disease signatures.

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. This work has been supported by funding from the National Science Foundation.
The Center for Biophotonics, an NSF Science and Technology Center, is managed by the University of California, Davis,under Cooperative Agreement No. PHY 0120999

BioBriefcase detection trains



Sensor development using microdot-array fiber-optic sensors

J. Carter, J. Marion, B. Colston, S. Brown, D. Maitland, K. Langry, M. McBride, R. Alvis, T. Wilson

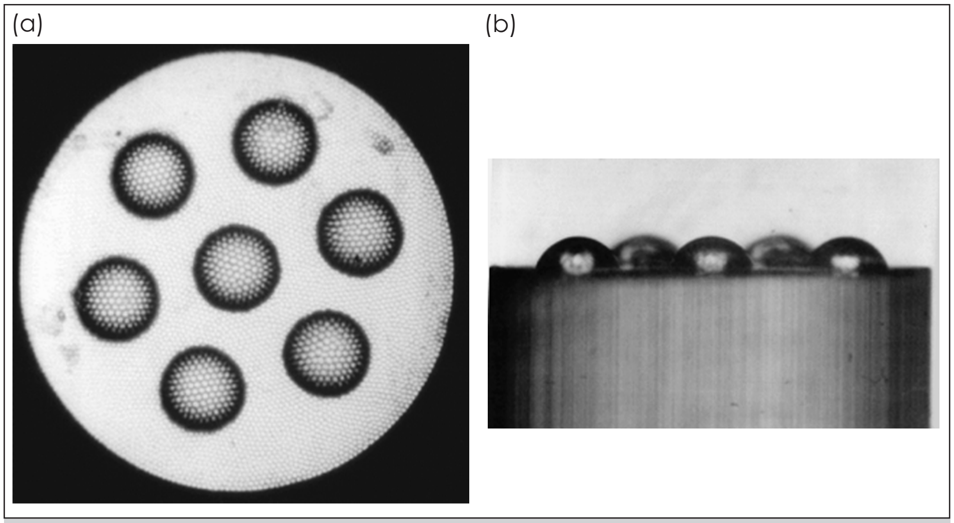
The goal of this project is to develop and demonstrate a reproducible, minimally invasive, optical-fiber-based sensor for rapid and in vivo measurements of biological biomarkers using the microjet printing process. If successful, this project will provide clinicians with a new diagnostic tool for making enzyme, blood/gas, and ion measurements.

In addition to the intended medical application, this type of miniaturized chemical sensor would also benefit the Laboratory's national security mission in chemical- and biological-agent detection.

The microjet process for printing indicator chemistries on image-guide fibers is a unique method for creating chemical sensors designed to detect and quantify one or more ligands or analytes in a fluid or airborne medium. The indicator chemistry contains one or more light-energy-absorbing dye(s) whose optical characteristics change in response to the target ligand or analyte. By spectrally monitoring these changes using fluorescence spectroscopy, the target ligand or analyte can be detected and quantified with great sensitivity. If multiple ligand-specific indicator chemistries are printed in a known pattern, these ligands or analytes can be simultaneously detected and measured using optical imaging techniques to spatially register each microdot. We have coined the acronym MiDAS (microdot array sensors) for this new sensor-fabrication methodology.

Historically, commercial development of fiber-optic chemical sensors has been slow because of the inherent difficulty of reproducibly and inexpensively fixing indicator chemistries on the tips of optical fibers. The lack of a reproducible technique results in high inter- and intrasensor variability, which increases the cost of sensor manufacturing since *each* sensor requires individual calibration.

During FY2001, we demonstrated that microjet technology can be utilized for overcoming these difficulties by "printing" indicator chemistries directly on the tips of optical fibers.



Ninety-mm-diam microdot array sensors "printed" on a 500-µm-diam optical-fiber image guide, showing (a) top view, and (b) side view.

The Figure shows a six-around-one pattern of microdots, each containing an ion indicator dye printed on the tip of a 500-µm-diam optical-fiber image guide. The Figure shows the excellent reproducibility of our fiber-printing process. Average and standard deviations for the diameter and roundness of these microdots are 93.3 ± 2.2 µm and 0.00072 ± 0.00023 µm, respectively. The fluorescent intensity of the indicator dye varies less than 2%. This example clearly demonstrates the capabilities of microjet technology for reproducibly printing a pattern of identical but spatially discrete sensing regions. Our approach is being investigated for use as a biosensor for in vivo multianalyte measurements.

During FY2001, we acquired a printing system for LLNL and began making engineering design changes so that it can be used for printing onto image-guide optical fibers. Meanwhile, we are working with a commercial supplier for our microprinting needs.

In FY2002, we will complete (1) all engineering-design work on the microprinting station, and (2) the development of the enzyme-based biomarkers. The latter will be combined with the continuing ion and blood/gas sensor work from FY2001.

Autonomous Pathogen Detection System (APDS)

Lawrence Livermore National Laboratory

Point-of-contact: Dr. John Dzenitis, 925-422-6695, john.m.dzenitis@llnl.gov.

An Autonomous Pathogen Detection System (APDS) unit is an automated, podium-sized system that monitors the air for all three biological threat agents (bacteria, viruses, and toxins). The system has been developed by Lawrence Livermore National Laboratory (LLNL) to protect people in critical or high-traffic facilities and at special events. The system performs continuous aerosol collection, sample preparation, and multiplexed biological tests using advanced immunoassays to detect bacteria, viruses, and toxins. More than ten agents are assayed at once. Current R&D work is incorporating polymerase chain-reaction (PCR) techniques for detecting DNA.

Single units can be operated to monitor a local space or a central conduit like an air-supply duct. In a more powerful application, a network of APDS units can be integrated with central command and control to protect larger areas. The APDS units can also be networked and integrated with other sensing and analysis systems to provide multifaceted detection and response capabilities. The portability of the APDS lends the system to deployment for special events, while the low level of labor due to autonomous operation makes long-term deployment cost-effective.

One of the most important aspects of the APDS is that it uses the same high-quality biological assays that are used by LLNL in its Biological Aerosol Sentry and Information System (BASIS) and by the Centers for Disease Control's Laboratory Response Network. These assays have the best sensitivity (lowest limit of detection) and selectivity (least chance of false positives) available.

APDS units have detected aerosol releases of live anthrax and plague in chamber tests at Dugway Proving Grounds in September 2002. Two units operated autonomously in an airport for four days in December 2002 without incident (see photo).

Demonstrated capabilities

- Autonomous operation (currently at one week).
- Continuous sampling, reporting as often as every 30 minutes.
- Aerosol collection at 200 to 3300 liters/minute (7 to 116 cfm).
- Assays for bacteria, viruses, and protein toxins
  - Multiplexed immunoassay panels (10 agents) deployed.
  - PCR development underway.
  - High-quality assays used by Biological Aerosol Sentry and Information System (BASIS), Centers for Disease Control, and Laboratory Response Network.
- Secure wireless and Ethernet communication.

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

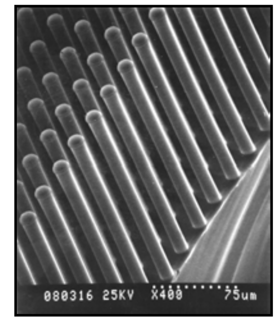
DNA Purification Sensor

What it does

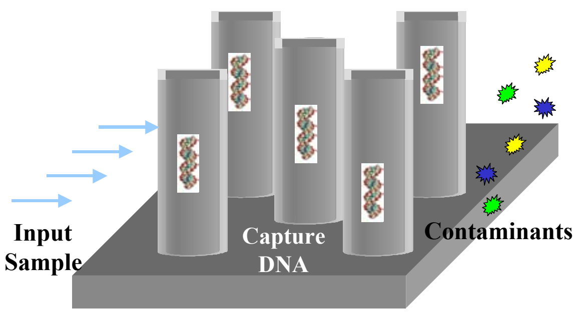
- Nanotechnology based system that helps to purify and concentrate systems prior to PCR
- Critical pre-treatment when sampling from the real world

Accomplishments/Status

- High aspect ratio pillars (40:1) successfully fabricated from Si
- Laboratory tested
- Prototype systems available



Technology



- Si Pillars capture and concentrate DNA to 1000x, while contaminants flow through cell

Business Model/Opportunity

- Patents filed by commercial partners
- Internal LLNL funding for incorporation into a disposable PCR device
- Currently under development with commercial partner
- Interest in joint research for other applications

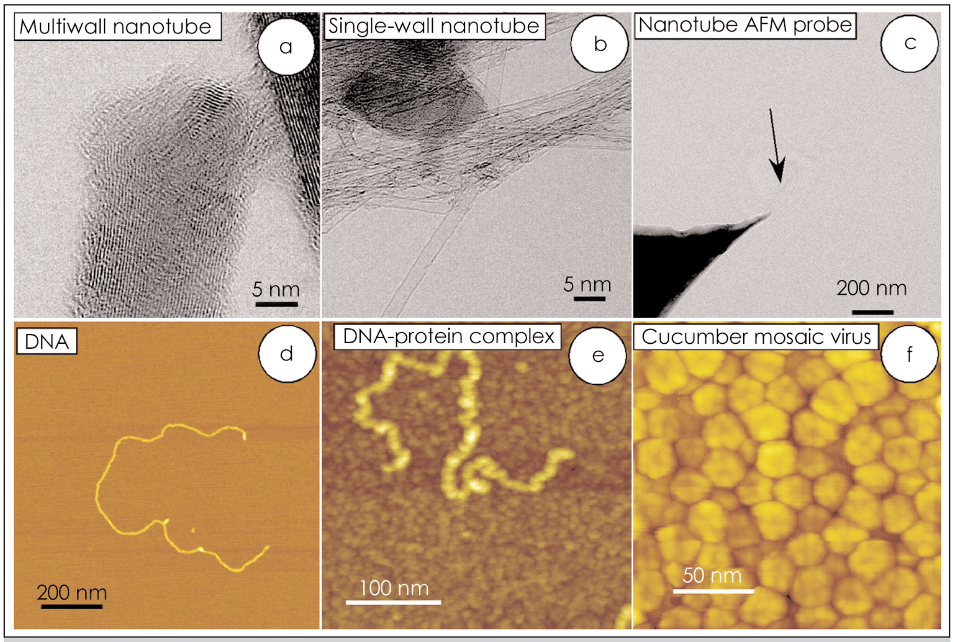
ENGINEERING

Applications of carbon-nanotube-based atomic force microscopy to proteomics and biological forensics

A. Noy, A. Malkin, J. J. De Yoreo

Determining the structure of biological molecules on the nanometer scale is one of the major challenges facing modern molecular biology. Conventional methods typically rely on x-ray analysis of protein crystals—a labor-intensive and time-consuming process. In addition, the difficulty of using x rays to analyze proteins increases with the size of the protein. However, the biggest challenge lies in obtaining the protein crystals for the analysis. Using current state-of-the art techniques in protein crystallization, it will take more than 100 yr to determine the structures of all the proteins coded by the human genome. Perhaps this estimate is over-optimistic considering that most of the easy-to-crystallize proteins have already been studied, and several large classes of proteins—membrane proteins, for example—are notoriously resistant to crystallization efforts. Developing new imaging techniques that do not require crystallization is very important for determining the structure of proteins. These new techniques will be invaluable for identifying the structure and function of biological agents that pose a national security threat, such as pathogenic viruses.

Over the past few years, we have demonstrated a powerful imaging technique that uses atomic force microscopy (AFM) for studying the structures and dynamics of macromolecules and macromolecular crystals. Because the resolution of the technique is limited by the size of the probe tips, the goal of this project is to develop the use of carbon nanotubes as probes for high-resolution AFM. This project supports the DOE's counter-proliferation mission.



New imaging techniques using carbon nanotubes are determining the structures of proteins: (a–c) show transmission electron microscope (TEM) images of carbon nanotubes and a carbon nanotube [indicated by arrow in (c)] used as a tip for atomic force microscopy (AFM); (d–f) show examples of biological imaging.

During FY2000, we developed the technology for mounting bundles of single-wall carbon nanotubes onto commercial AFM probes and demonstrated that these nanotube probes exhibit substantially better resolution than conventional AFM probes. However, mounted carbon-nanotube tips still fell short in several key areas: (1) the probe-tip radii (~4 to 5 nm) were still too large to obtain the desired level of structural information, (2) the probes were unstable in a fluid environment, and (3) the manufacturing process was extremely labor-intensive and poorly controlled. As a result, we decided to shift our focus and use a catalytic chemical vapor deposition (CVD) process to produce the carbon nanotubes and carbon nanotube tips for AFM.

During FY2001, we designed, built, and refined the apparatus for CVD synthesis of carbon nanotubes. Establishing process conditions and controls allowed us to produce "designer" multiwall and single-wall carbon nanotubes of controlled dimensions and structure [see Figs. (a,b)]. We also developed and tested the protocols for growing carbon nanotubes on the AFM tips using this technology [Fig. (c)]. This new generation of probes exhibited a significant increase in resolution over the older generation of the AFM probes. In addition, the reproducibility of the probes has drastically improved. We are now able to fabricate AFM probes that terminate either in a single carbon nanotube or in a bundle of two to three nanotubes. We also used AFM probes made of carbon nanotubes to image proteins, viruses, and DNA adsorbed on a mica surface. The images in Figs. (d–f) demonstrate that this technique is indeed a valuable tool for obtaining unique and important structural information about these objects. A paper is in preparation.

EM Sensors

Electrical Resistance Tomography (ERT)

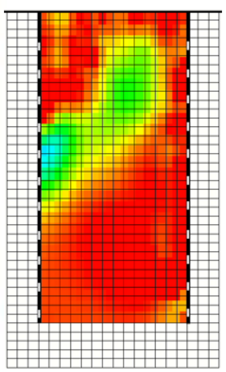
What it does

- ERT uses low frequency electrical energy to determine the subsurface electrical resistivity distribution between multiple embedded electrodes. For in-situ applications, the electrodes are placed on the ground surface and/or in boreholes.
- ERT has made significant contributions to the fields of hydrogeology, environmental remediation, oil reservoir management and various engineering investigations through the development of 2-D and 3-D subsurface geophysical images.

Accomplishments/Status

- ERT is a relatively new geophysical imaging process pioneered by LLNL in the late 1970's. Specific ERT applications currently funded by DOE include: landfill cap monitoring, monitor the sequestration of underground carbon dioxide, storage tank leak detection and monitoring, plus plume detection and monitoring for underground contaminate remediation processes.

Technology



- Multiple patents and invention disclosures (patent pending) exit covering the method, processes and techniques including the data processing algorithms. The IP is encumbered somewhat through the licensing of the Laboratory's underground stripping technology.

Business Model/Opportunity

- Government funding continuing to apply ERT monitoring capabilities primarily to underground remediation processes.
- Industrial partners being sought to expand commercialization of the technology through technology licensing, Cooperative Research and Development (CRADA) and/or "work for hire" agreements.

ENGINEERING

Gas Sensors

Hand-Held Gas Chromatography (GC) System

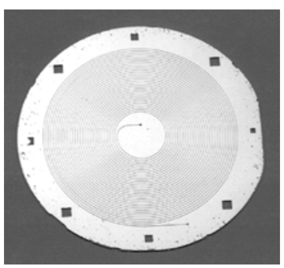
What it does

- The hand-held GC is a small (8”x 5”x 3”), light weight (< 8 lbs.), portable self contained GC system which can be used for standard GC applications.
- Micro-electro mechanical system (MEMS) based silicon column and detectors provide a small portable GC with fast analysis times (30 - 40 seconds for many light gas mixtures).

Accomplishments/Status

- The hand-held GC system was developed and demonstrated for the DOE sponsor in late 1999 with ppm sensitivity.
- Continued detector development and system upgrades in 2000 & 2001, including a new glow discharge detector developed in 2001, which increased system sensitivity to the low ppb levels.

Technology



- The key system components include: MEMS-based silicon column with built-in heater and MEMS-based thermal conductivity detector (ppm) and/or glow discharge detector (ppb).
- Multiple patents and invention disclosures (patents pending) covering the column, detector designs and overall system.

Business Model/Opportunity

- Government funding continuing to upgrade and enhance the existing system (reduce size, add sniffer and preconcentrator capability, etc.).
- Industrial partners being sought to commercialize technology through technology licensing, Cooperative Research and Development (CRADA) and/or “work for hire” agreements.
- Target markets include standard portable/field GC and process control applications.

ENGINEERING

Portable GC-MS

What it does

- LLNL’s portable GC-MS replaces the full functionality of a standard benchtop GC-BS (circa 250 pounds) with a 50-pound, field portable system.
- Permits in-the-field analysis of samples for timely, low-cost GC-MS applications such as forensics, environmental clean-up, etc.

Accomplishments/Status

- We have developed a light-weight, field portable GC-MS system (shown at left).
- Developed for FBI; successfully deployed in many field applications.

Technology

- Current version uses commercial capillary columns and a newly designed GC oven.
- New quadruple MS in custom vacuum housing.
- Tiny, twin turbomolecular pumps maintain low operating vacuum.
- Laptop computer controls system and analyzes data.
- Next generation design underway (e.g., MEMS-based GC).

Business Model/Opportunity

- Prototype system fully developed.
- Commercialization is possible via licensing and possible collaborative work with LLNL.
- Government applications (forensics, environmental monitoring) partially implemented.
- Commercial uses need further exploration.

ENGINEERING

Hydrocarbon Sensors

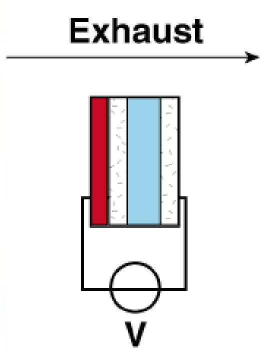
What it does

- Applications for the on-board monitoring of automotive exhaust gases to evaluate the performance of catalytic converters.
- Low cost, rugged, sensitive, simple to fabricate, and does not suffer cross-sensitivities.
- Responds in both fuel rich and lean-burn conditions.

Accomplishments/Status

- Evaluated at Ford Research Laboratory under laboratory and dynamometer testing conditions.
- Stable response throughout test cycle.
- Results correlated well with concentration of hydrocarbons in exhaust gas.
- No sensitivity to CO.
- Minimized effect of oxygen on sensor performance.

Technology



- Dehydrogenation based sensor.
- Proton conducting electrolyte sandwiched between two electrodes (green).
- At least one electrode is covered with a hydrocarbon decomposition catalyst (red).

Business Model/Opportunity

- Applications for automotive and industrial controls.
- Patented under CRADA with US automotive.
- Looking for R&D partners with expertise in design of automotive and industrial sensors to improve packaging of sensor and commercialize.

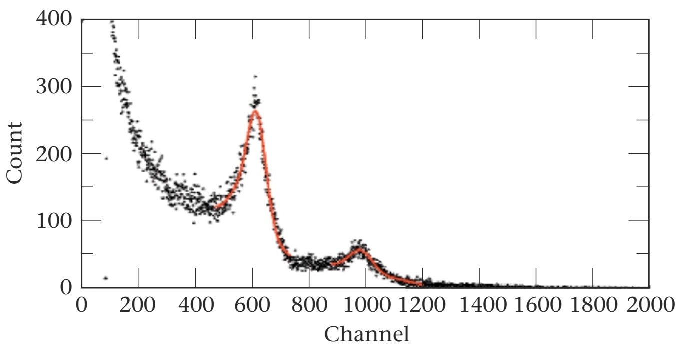
ENGINEERING

Nuclear Sensors

A Full-Volume-Imaging Gamma-Ray Detector for Enhanced Sensitivity

K. P. Ziock, D. Archer, A. Dougan, J. Luke, S. Prussin

To address the problem of smuggled nuclear materials, we are developing a new class of gamma-ray detector that will significantly enhance the detectability of such materials. The detector works on the principle of Compton scattering. In this process, gamma-rays (~0.2 to 2.0 MeV) from the nuclear materials "bounce-off" the electrons in the detector, depositing energy at the scatter location. The recoiling gamma-ray is also stopped and its energy and location of capture measured. With the information from the two deposition sites, we can recreate the kinematics of the Compton scatter, and determine the direction of incidence of the gamma-ray within a narrow ring of directions. During operation, the source will appear as a region of overlapping rings in the image. Our simulations show that the ratio of ring solid angle to the solid angle of all directions reduces background radiation by a factor of 200, a tenfold increase in the detectability of smuggled sources compared to a classic omnidirectional detector.



A spectrum of a ^{133}Ba source measured with the system using a microwell readout plane. The high-energy peak (~channel 1000) is identified as the 81 keV radiation from the source, the lower energy peak (~ channel 600) is identified as the K-fluorescence escape peak from this line. Due to the small volume of the active area of the detector (~ 2 × 2 cm) the escape peak is much larger than the primary peak.

During FY2000, our goal was to bring the apparatus constructed in FY1999 on line and test the system performance for use as a full-volume gamma-ray detector. The instrument comprises a volume filled with high-pressure noble gas (xenon) in which the gamma-ray interactions create electron–ion pairs. Using an applied electric field, electrons are made to drift toward a readout plane, where the number of electrons and their location is read out.

The detector uses both high pressures (up to 50 atm) and cryogenic gas handling techniques. We first demonstrated that the system could operate safely, and obtained the necessary approvals to begin experiments. Next, we focused on developing the readout plane used to amplify the number of electrons detected and to determine the location of each event. A planer charge collector was used to bring the system on line and verify our ability to detect charged particles from the ambient cosmic-ray flux traversing the unit. A subsequent collector, a wire-plane readout, provided some charge amplification and demonstrated the ability to detect gamma-rays. We concluded with a microstructure readout plane, manufactured using microlithography techniques. This plane is required for obtaining the three-dimensional position resolution and simultaneous charge amplification needed for full Compton event reconstruction. The Fig. shows a sample spectrum obtained with the microstructured readout.

Our results from the system, particularly when used with the microstructure readout plane, confirm that the detector operates as expected, correctly amplifying and detecting the gamma-ray-induced electrons generated in the xenon gas. We found no technical obstacles to successful construction of a fully functional full-volume detector. Clearly, further work remains on the design and construction of cost-effective readout planes that are suitable for operation at high pressures. The system constructed under this project provides an excellent testbed for such future efforts. This project is complete.

Nanoscience and nanotechnology in nonproliferation applications

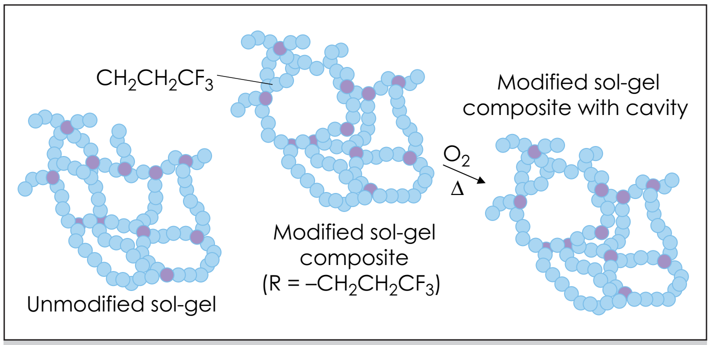
B. D. Andresen, J. G. Reynolds, T. M. Tillotson, P. R. Coronado, S. R. Kane, S. E. Letánt, B. R. Hart

Chemical and biological weapons (CW and BW) are now recognized as major threats to national safety and security. One approach to combating CW and BW is to monitor production activities through collection and detection methods. Commercial, polymer-utilizing tools developed for CW field collections have good selectivity. However, such tools also must have unprecedented levels of sensitivity. The high sensitivity is needed because only trace [parts per billion (ppb)] or ultratrace levels [parts per trillion (ppt) or less] of CW- and BW-related materials are found in the environment. Specific selectivity is necessary to distinguish CWs and BWs from naturally occurring compounds.

Nanostructured materials—materials that have surface features and pore structures on the nanometer scale—can potentially be more specific, yet more versatile, than traditional polymers. Materials attractive for this use are silica sol-gels, mesoporous silica and carbon nanotubes, and porous silicon (Si). In this project, we are tailoring—through chemical and surface modification—these nanostructured materials to be the new generation of highly efficient, small accumulators of and sensors for CW and BW compounds.

This project capitalizes on the strengths of LLNL, utilizing expertise in synthesis and development of nanostructured materials and their application to forensics.

During FY2001, we progressed in the development of silica sol-gels, carbon nanotubes, and porous Si as accumulators and sensors. We began modifying silica sol-gels to provide designed cavities and reaction sites that increase specificity for target CW compounds. For example, we synthesized specific cavities in the nanostructured framework by first incorporating organic substituents and then removing them by air oxidation (see Figure). To increase the selectivity of these cavities, we began designing binding sites for CW compounds by adding metals such as scandium and lanthanides into the silica framework. We fine-tuned the synthetic methods by using alkoxide condensation reactions. For better selectivity in aqueous environments, fluorinated groups were incorporated into the sol-gel matrix, thereby making the material hydrophobic.



Effects on pore structure of incorporating an organic substituent group (R) into a silica sol-gel framework. Note the physical space in the structure after the R group is oxidized away.

Using commercially available, single-wall nanotubes, we developed new activation techniques that enhance their collection activity. Initial test results with nanotubes in unique (patentable) collection configurations showed that these modified carbon nanotubes have 3 to 4 times the activity of Carboxen—a polymer that is the industry standard for the collection of CW-related compounds. Silicon polymers were used as binders in the development of thin-film coatings that contain these materials; such coatings are important for the ultimate, real-time application of nanostructured collectors.

Recent work in universities has shown that the photoluminescence properties of the surface of porous Si can be used in the detection of CW and BW. Our approach is to utilize photoluminescence for detection through anchoring CW-active enzymes on the porous Si. By the end of FY2001, we had begun production to isolate the CW-active enzyme, produced test pieces of porous Si, and developed linkages for the enzyme to the porous surface.

In FY2002, we will continue enhancing the specificity of these materials by (1) designing cavities in the sol-gel materials, (2) increasing the size of the nanotubes and modifying the activation procedures, and (3) attaching the CW-active enzyme to the surface in the porous Si materials. Our overriding goal will be to prepare new materials that have increased collection efficiencies and analytical specificity.

Optical Sensors

Speckle Reduction for LIDAR Using Optical Phase Conjugation

M. W. Bowers, C. Kecy

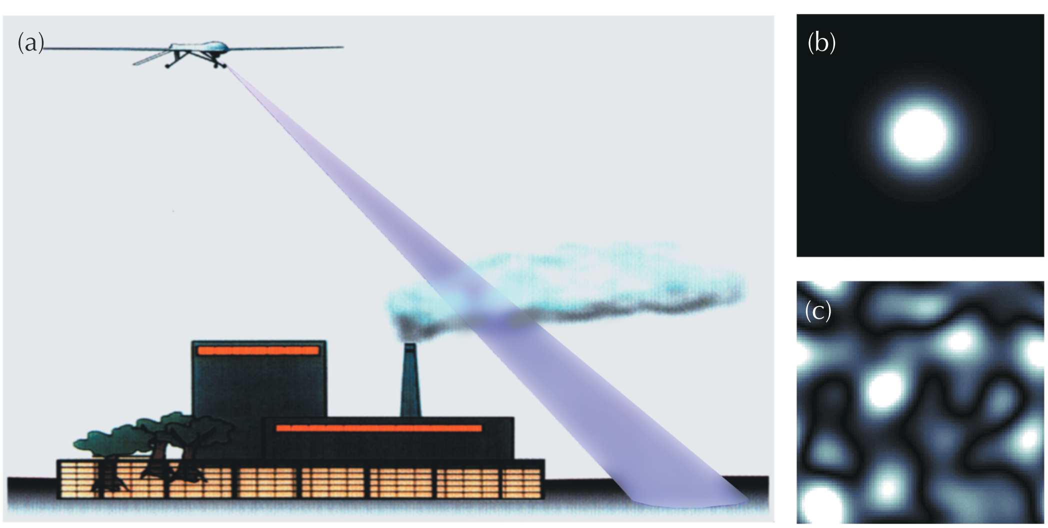
Remote detection systems can be used to monitor the production and use of chemical, biological, and nuclear weapons as well as environmental conditions around the world. Light-intensity detection and ranging (LIDAR) is well suited for these applications. In a LIDAR system, a laser beam is transmitted toward an area to be probed. The return scatter from an aerosol or from the topographical background is detected and measured. LIDAR systems are complicated by noise sources. For example, speckle results when light scatters off a diffuse surface and interferes with itself to create light and dark spots at the detector plane. Optical phase conjugation is a nonlinear optical method of removing speckle by exactly reversing the light so that it returns to its point of origin and appears similar to the way it did before it left. The result is uniform illumination of the detector and reduction in the associated noise. Our goal in this project has been to show that it is possible, under most normal LIDAR operating conditions, to use optical phase conjugation to mitigate the effects of speckle.

During FY1999, we focused on studying phase-conjugation properties in the laboratory and evaluating how phase conjugation would perform under conditions similar to those found on LIDAR systems. During that year, we found that it is possible to correct for speckle under most normal operating conditions. However, our work revealed that bulk, nonlinear optical approaches to the phase-conjugation problems could not handle the extended sources that would be present in a fully speckled field. After studying liquid-filled and solid optical waveguides to determine their usefulness for such an application, we found that the power levels necessary to achieve adequate phase-conjugation reflectivities in the liquid-filled waveguide caused localized heating. This heat, trapped inside the waveguide, could not be conducted away as it is in a bulk or flowing system, and quickly formed bubbles that prevented phase conjugation from occurring.

Our dual objectives for FY2000 were to (1) modify the LIDAR system for pulse width and energy so that it could accommodate the optical phase-conjugation system, and (2) find an appropriate solid-state waveguide phase conjugator that would allow for high-fidelity phase conjugation at the 1.5-μm wavelengths we were using.

Our first choice for a solid-state waveguide phase conjugator consisted of single-crystal, tapered sapphire fibers, a theoretically "perfect" material for our phase conjugator. However, we were not able to reach the stimulated-Brillouin-scattering (SBS) threshold, even at power levels far higher than theory would predict. Researchers at the University of Rochester, collaborators during the first portion of the project, are looking into this attribute of SBS suppression to see if it can be exploited as a method of suppressing SBS in high-power fiber-optic systems such as long-haul telecommunications systems.

Our second choice, composed of tapered silica fibers, showed good phase-conjugate qualities in our experiments. However, tapered silica fibers do not have the input acceptance angle that is necessary to completely capture the entire speckle field and allow for high-fidelity phase conjugation. At year's end, we were pursuing the possibility of expanding this input numerical aperture and decreasing the acceptance angle of the receiving telescope in the LIDAR system to improve the conjugate fidelity of the system.



Speckle reduction as used in (a) one possible application of a light-intensity detection and ranging (LIDAR) system. The speckle was reduced by optical phase conjugation in (b); optical phase conjugation was not used in (c).

High-Sensitivity, Optically Polarized NMR of Surfaces in Materials Science and Biology

S. E. Hayes, M. Balooch, L. N. Dinh, J. A. Reimer, A. K. Paravastu

Detection of nuclear magnetic resonance (NMR) signals from rare spins (e.g., nuclei with low isotopic abundance, species at surfaces or interfaces, or small sample quantities) is a significant challenge. Although NMR is a powerful tool for determining structures, local bonding geometries, and molecular dynamics, conventional NMR is a bulk-averaged technique that lacks spatial selectivity and suffers from low sensitivity (~10^{20} NMR-active nuclei are needed for detection). Recent developments have combined NMR with direct, optically polarized NMR (OPNMR). In OPNMR, laser light is used to excite spin-polarized electron-hole pairs, which in turn polarize nuclear spins to which they are coupled. Because NMR amplitudes are directly proportional to the nuclear-spin polarizations, signal enhancement factors of about 10^5 are possible.

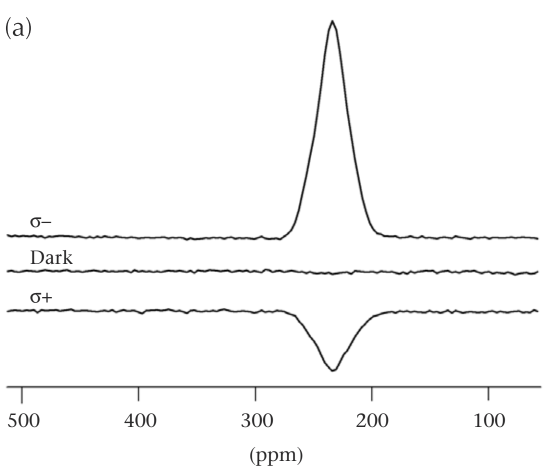
The aim of this project is to provide a new NMR capability for LLNL that has both high sensitivity and spatial selectivity and that can be used to analyze systems with dilute nuclear spins. Examples are surfaces or interfaces (i.e., semiconductor/insulator barriers and nanoclusters) or very small quantities of samples (e.g., biological samples and trace analyses). A number of potential applications can be realized, such as the investigation of metal hydriding, membrane protein structures, cell receptor sites, and semiconductor heterostructures.

During FY2000, we designed and constructed an OPNMR apparatus that consists of homebuilt, radio-frequency (RF) transmission-line NMR probes; a low-temperature cryostat; and a vacuum system outfitted for optical access. The hardware is configured to permit optical excitation at the sample space using a tunable laser. We observed OPNMR signals from single-crystal wafers of GaAs. These signals exhibit a dependence on the polarization of the laser, which creates positive and negative circularly polarized light. The NMR signals become absorptive or emissive depending on the degree and sign of circular polarization [see Fig. 1(a)], which indicates that the angular momenta of the nuclear spins and the photon spins are coupling. This OPNMR signal develops with increasing irradiation time as more nuclear spins become polarized over time. By comparison, an equivalent experiment done in the "dark" (without laser illumination) resulted in an attenuated signal.

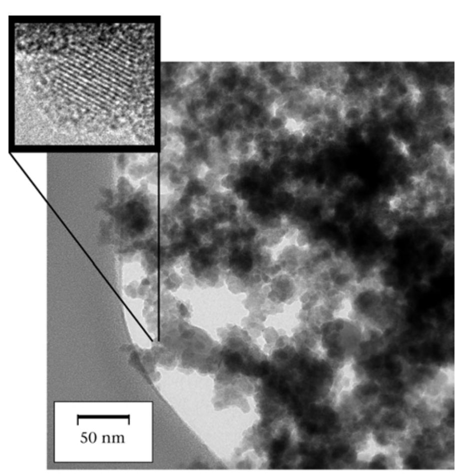
We also synthesized GaAs nanoclusters through laser-ablation methods using ultrashort, pulsed-laser deposition. Films deposited onto various substrates were characterized by x-ray diffraction, atomic force microscopy (AFM), and transmission electron microscopy (TEM). Their structure [see Fig. 1(b)] consists of a crystalline core surrounded by an amorphous, mixed-oxide outer shell. The crystalline nature of the GaAs clusters was confirmed, and we examined the distributions of cluster sizes for various preparation conditions. When we evaluated chemical etching and passivation of these clusters and the concomitant photoluminescence (PL), we found that passivation increases the strength of the PL signal for both single-crystal wafers and cluster samples. We are probing this connection between photoluminescence and OPNMR because optical absorption is a prerequisite for optical polarization, and the electronic structure inherent in the material will be reflected in the PL spectra.

In FY2001, we will continue our research in OPNMR methods, applying the technique to (1) other Group III-V materials (e.g., InP), and (2) possibly also Group II-VI (i.e., CdSe) and Group IV (e.g., silicon) materials. We will also continue our nanocluster-synthesis activities and apply our OPNMR techniques to these materials to understand their structure, electronic states, and surface chemistry.

(a)



(b)



Results of work with optically polarized nuclear magnetic resonance (OPNMR) and the connection between photoluminescence and OPNMR, showing (a) OPNMR spectra for a circularly polarized light (σ– and σ+) and an equivalent dark experiment, and (b) a transmission electron microscopy (TEM) image of GaAs nanoclusters. The inset image in (b) shows lattice fringes from one cluster. The presence of both absorptive (pointing upward) and emissive (pointing downward) peaks in (a) indicates that the polarized light is having an effect on the NMR signals.

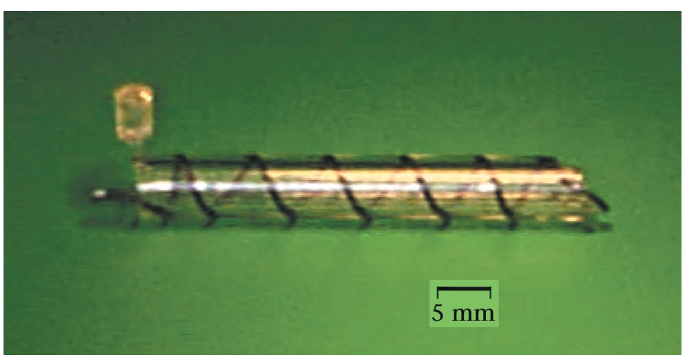
Advanced Imaging Catheter

P. Krulevitch, D. Hilken, J.-U. Kluiwstra, R. Miles, D. Schumann, K. Seward

Catheter-based, minimally invasive surgery is performed by making a small incision in a main artery, inserting a long, hollow tube (catheter), and navigating through the artery to the treatment area. Once positioned, the catheter is used to deliver devices such as angioplasty balloons and stents for opening occluded arteries. Over 700,000 catheter procedures are performed annually. The advantages of this technique—reduced patient trauma and fast recovery—make it one of the fastest-growing surgical procedures. In most cases, catheters are positioned using radiography for visualization and manual manipulation for navigation and positioning of the device. However, the procedure has its difficulties: catheters can be as long as 2 m and can taper down to outside diameters of 800 µm, with artery channel diameters of 500 µm.

The objective of this project is to enhance the physician's navigational abilities by producing a compact catheter that offers imaging and active control for guiding and positioning the distal end (i.e., the end inside the body). Clinicians have emphasized that such a device would be a tremendous breakthrough. In addition, this technology has the potential for noninvasive or minimally invasive imaging of explosives or weapons systems.

Over the past three years, we have applied LLNL's expertise in optical and ultrasonic imaging, microfabrication, and modeling toward the development of an advanced catheter. The emphasis for FY2000 was on catheter articulation, mesoscale polymer molding and extrusion, and forward-looking ultrasound. In collaboration with physicians at the University of California, San Francisco (UCSF) and the University of California, Davis (UCD), we observed several catheter-based procedures and discussed how an articulating, imaging catheter could improve their patient's outcomes. Prototype devices incorporating shape-memory alloy (SMA), shape-memory polymer (SMP), and hydraulic actuation were fabricated and tested. The Fig. shows an SMP catheter tip with an embedded SMA spring. Heating the composite device just above the SMP transformation temperature causes it to expand and lengthen; heating above the SMA transformation temperature causes it to contract, enabling advancement of the tip when combined in series and actuated peristaltically. By fabricating and testing a 1-in.-long, 0.16-in. i.d., 0.08-in. o.d., hydraulically actuated, molded silicone catheter tip, we demonstrated repeatable 90˚ bending. In addition, a fluid-filled, 1/4-in.-diam polymer bellows increased in length 1/2 in. when heated by a laser.



Our advanced, composite catheter tip, showing a prototype shape-memory polymer (SMP) tip with an embedded shape-memory alloy (SMA) spring.

During FY2000, we also investigated using forward-looking ultrasound to aid in guiding a needle during an intravascular liver-bypass procedure known as transjugular intrahepatic portosystemic shunting (TIPS). In this procedure, a single-element piezoelectric transducer is placed at the end of the articulating catheter and periodically pulsed. Harder tissues reflect more acoustic energy compared to blood-filled veins, thus enabling navigation through a diseased liver. To demonstrate the principle, we placed a single-element, circular transducer in a water bath 40 mm from a vessel-mimicking tube. The first interface was the front wall of the tube, and a large amount of energy was reflected back to the transducer. A second, much smaller reflection was observed coming from the back wall of the tube. This demonstrated the ability to use ultrasound to measure both the distance to the vessel and the size of the vessel. Numerical simulations optimized the size and shape of the transducer.

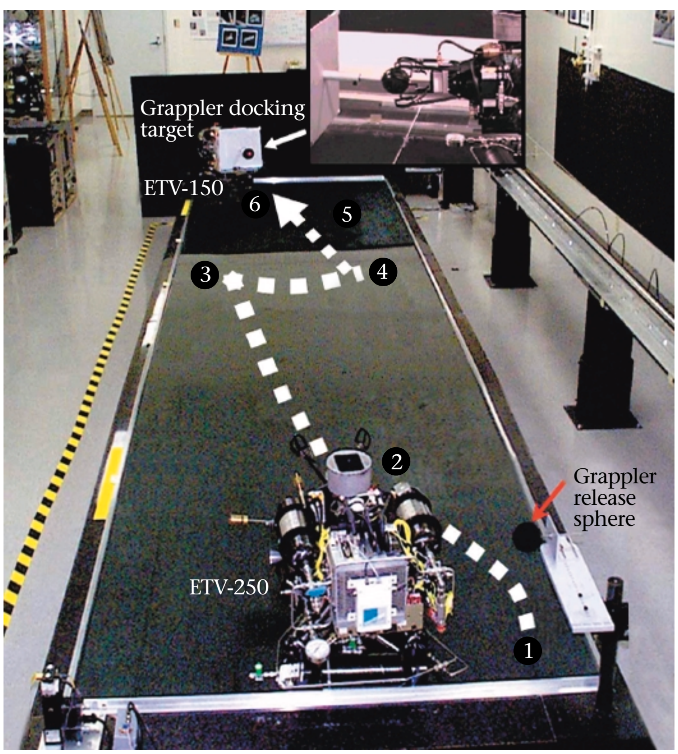
Several patents have been filed from this project, and two have been issued.

Autonomous On-Orbit Proximity Operations and Docking Capability

A. Ledebuhr, L. Ng, M. Jones, B. Wilson, J. Whitehead

The capability for autonomous proximity operations, such as close-in inspections, docking, and formation flying of a microsatellite around another target satellite in low-Earth orbit would open up a host of potential new missions that could revolutionize robotic operations in space. However, these capabilities must first be developed and demonstrated on the ground. The goal of this project was to demonstrate, in the laboratory, the critical capabilities and technologies necessary for these autonomous operations.

During the course of FY2000, we completed the development of a prototype engineering test vehicle, the ETV-250, which was designed to carry out repeated docking experiments on a simulated zero-gravity, five degrees-of-freedom (DOF) dynamic air table. This vehicle was conceived as a forerunner of future microsatellites with the ability to perform complex proximity operations and docking maneuvers in space. We prototyped a 3-D, vision-based, object-tracking system that uses stereo-ranging and laser-ranging systems to support a series of autonomous docking functions. A major development consisted of an integrated, proximity-operation sensor (IPOS) system along with its avionics package and the software necessary to control and operate it. In addition, we began characterizing a miniaturized, hot-gas-driven, pumped propulsion system that uses hydrogen peroxide (H_2O_2) as a safe, nontoxic propellant. Once fully developed, this system will enable the precision on-orbit maneuvers required for these missions. A cold-gas propulsion system was used in the docking target (ETV-150) and ETV-250 vehicles for ground testing.



Numbers (see text for explanation) indicate the autonomous docking sequence of our prototype engineering test vehicle (ETV). The inset shows the final successful docking, with the robotic arm grappling the sphere mounted on a target vehicle.

To demonstrate proximity operations and docking capability, the ETV-250 was equipped with a smart sensor head and several intelligent software modules. The sensor head included an on-axis, high-resolution camera for object recognition; a robotic grappling arm with four fingers for docking; a pair of stereo cameras to provide stereo vision and range; an inertial measurement unit (IMU) for vehicle stability and control; and a laser ranger for millimeter-level precision translation control. The smart sensor head included a Star Tracker camera to provide updates to correct the slow drift in the vehicle's IMU. This function was not used in the indoor tests.

The Fig. shows a typical docking experiment. The vehicle floats on a spherical air bearing, which is mounted on a tripod that in turn floats on a cushion of compressed air beneath the tripod's footpad disks. This configuration allows near-frictionless translational motion to any position on the table and over a large range of vehicle angular orientations (in roll, pitch, and yaw). The experiment was set up on a 3- by 8-m table with a docking target (ETV-150) at the far end and the docking vehicle (ETV-250) at the near end, where it was initially secured to a mooring station. For the autonomous docking task, the test vehicle executed a series of maneuvers as marked on the Fig.: (1) autonomously release from a mooring station (note grappler release sphere), (2) slew to acquire the target with the high-resolution camera, (3) estimate target range and bearing from the stereo pair, (4) advance to about 2 m from the docking surface, (5) perform correction maneuvers to align itself with the surface normal of the ETV-150 target for the final approach and advance to the target using precision laser-range information, and (6) activate the grappler to secure the docking sphere.

In actual space operations, the docking vehicle could either (1) first circle the target to reconstruct a 3-D object surface map from the stereo imagery so as to identify the location of the object to be grappled, or (2) operate in a telerobotic mode with a link to a ground-control station. The next step in the development of this vehicle would be to further enhance its dynamic capability by using a H_2O_2-pumped propulsion system to increase the capabilities and range of vehicle maneuvers.

A patent application for the concept has been submitted.

MEMS Based Sensors for Vision Sensing

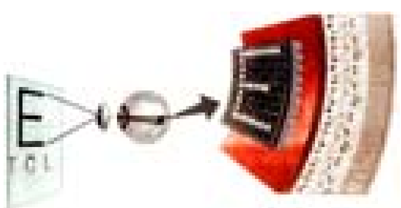
What it does

- Flexible, conformable, and biocompatible sensor array that is 4mm x 4mm x 0.1mm.
- Can be used to stimulate nerve tissue.
- Designed to communicate via RF signals.

Accomplishments/Status

- Polydimethylsiloxane (PDMS) has been used previously to fabricate MEMS devices at LLNL.
- Previous experience precisely patterning electrodes through the sputtering, electron beam evaporation, and electroplating of platinum, titanium, iridium oxide onto substrates.

Technology



- Polydimethylsiloxane (PDMS) substrate is flexible and biocompatible; perfect choice for implantation.

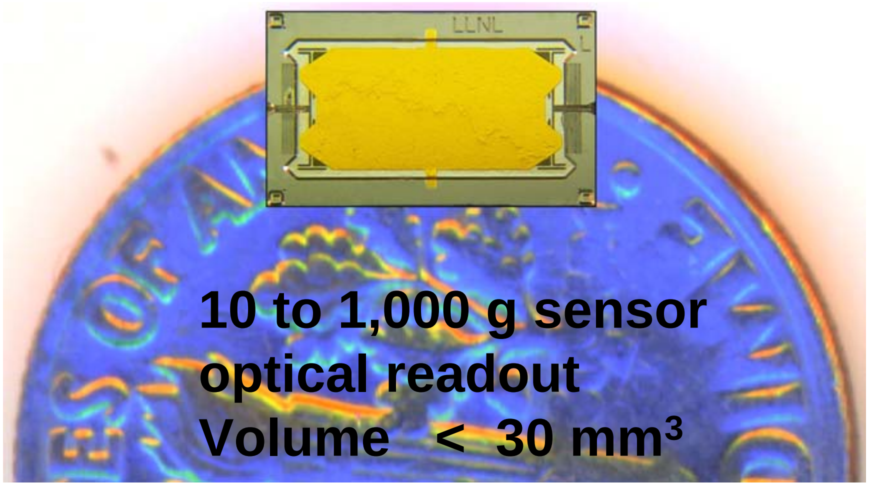
Business Model/Opportunity

- Applications for Public Systems and Healthcare.
- Currently funded by DOE for multilab CRADA.
- Patent pending.
- Looking for R&D partners with strengths / alliances in RF / wireless communication.

ENGINEERING

MEMS Fiber Optic Microaccelerometer

What it is



Status

- LLNL tests from DC to several kHz
- - 50°C to + 70°C test range
- USPO patent application
- Wafer scale fabrication and packaging done in FY2002
- Work continuing on improved packaging and miniaturization

Technology

- Micromachined silicon wafer forms proof mass, mirrors, springs
- Pyrex wafer sandwich packaging
- Multi-mode optical fiber
- Readout system uses FISO, Inc. white light Fabry-Perot system
- Passive, small, hermetic seal

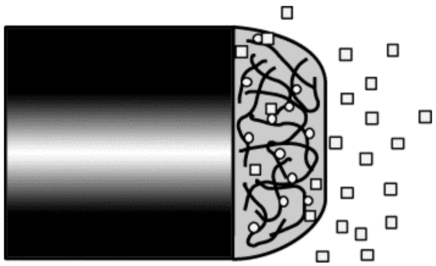
Applications / Opportunities

- LLNL internal program application funding to continue in FY2003
- Industrial partners may assist in commercial applications
- Broad applications include vehicles, industrial apparatus, motion sensing, scientific instrumentation

O15

Optochemical Sensors

What it does



- Non-invasive chemical sensor for quantitatively monitoring aging of material or amount of chemical species present.
- Chemical structure of fluorophore can be altered to fluoresce at a desired wavelength.

Accomplishments/Status

- Currently used to remotely monitor aging in nuclear weapons.
- Also successfully used in animal tests with fiber-optic percutaneous system and fully-implanted transcutaneous illumination.
- Relationship between molecular structure and wavelength of fluorescence has been established.

Technology

- Use of Photoinduced Electron Transfer (PET) gives “switchable” fluorescent sensors.
- Chemical structure of fluorophore can be altered to fluoresce at a desired wavelength.

Business Model/Opportunity

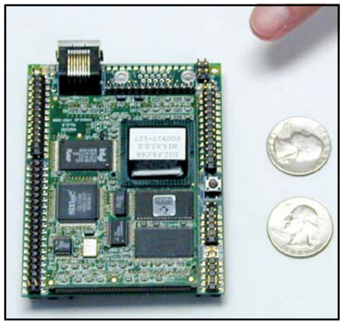
- Applications for Industrial Automation, i.e., process control, environmental, and Healthcare.
- Multiple patents and patent applications on chemical structure of fluorophores, the attachment to a polymer substrate, and implantation method.
- Looking for R&D partners with strengths in collection and transmission of optical data.

ENGINEERING

RF Sensors

Wireless Sensor Network for Seismic Monitoring

What it does

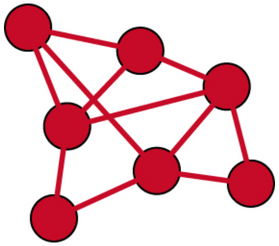


- An economical, wireless communication node for the construction of self-configuring, self-healing sensor networks.

Accomplishments/Status

- Communication nodes were successfully developed in FY01 under an LLNL Engineering Technology Base reduction to practice project. Self-configuration, self-healing of small arrays was demonstrated.
- Development will continue in FY01 with addition of inertial sensors and the demonstration of data collection with a full, multi-node seismic array.

Technology



- The nodes utilize readily available commercial off-the-shelf (COTS) hardware. LLNL developed and implemented network self discovery protocols for self configuration and ethernet routing. Nodes are ideal for monitoring large infrastructure where networks can self-configure and self-update over time.

Business Model/Opportunity

- Many existing LLNL programs in defense, energy and environmental applications can immediately utilize technically mature wireless sensor networks.
- Technically successfully and practically economical wireless sensor network technologies will attract work-for-others in a wide breadth of applications.

ENGINEERING

Asset Protection Sensor

Key Features

- Air-dropped or hand deployed
- Detects personnel/ vehicle motion
- Battery operated (6 days on 2 ea. AA batteries)
- Covert RF signal
- RF local-link or IR Sat-com link
- All weather day/night operation

Description

The Asset Protection Sensor is a battery operated radar sensor suitable for use as an intrusion sensor or with a transponer as a warning device. Sensitive receiver detects very slow (0.1”/sec crawling) to very fast (40 mph) motion. Sensor can be air dropped or hand-placed and emits an IR sat-com signal. Optional indicator LED’s report sensor status. Available only to US government agencies including DoD military. Unit transmits a low observable signal (one fiftieth cell phone signal strength) - difficult to detect. Procuring authority responsible for regulatory approvals.

	Size	Weight	Power
Asset Protection Sensor	2.4” x 2.4” x 2.4”	8 oz.	30mW

University of California
Lawrence Livermore National Laboratory

ASSET PROTECTION SENSOR

UCRL-PRES-146514

General Features

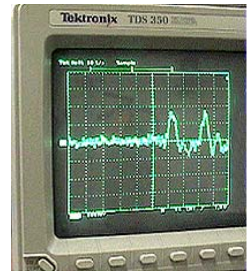
Two-Part Unit

Radar

- Human target
- 60 mph max. speed
- 0.001 mph min. speed (crawl)
- Stealthy (low-signature) signal
- 20 meter max. range
- AA Batteries, 2 ea.

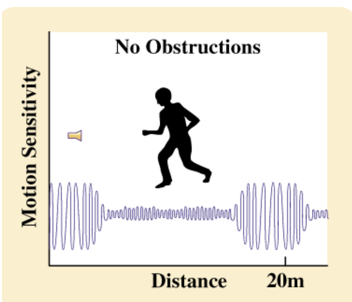
Signal Output

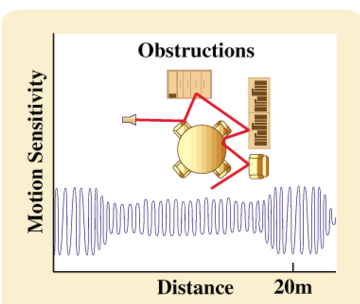
- Adjustable Sensitivity
- Reports to Radio Transmitter
- Continuing Operation
- FCC Compliant

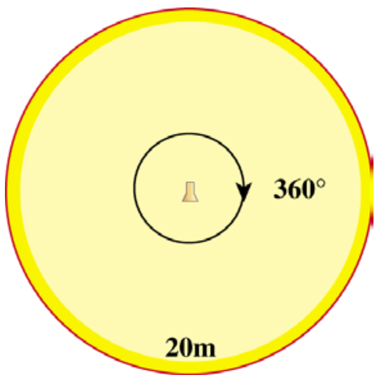


Typical Signal Output

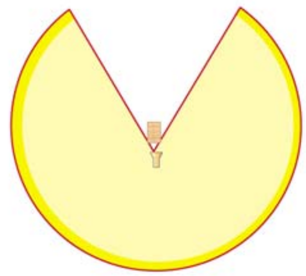
Typical Signal Output



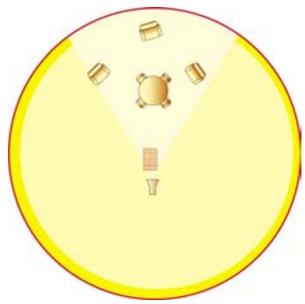




Signal Shadowed



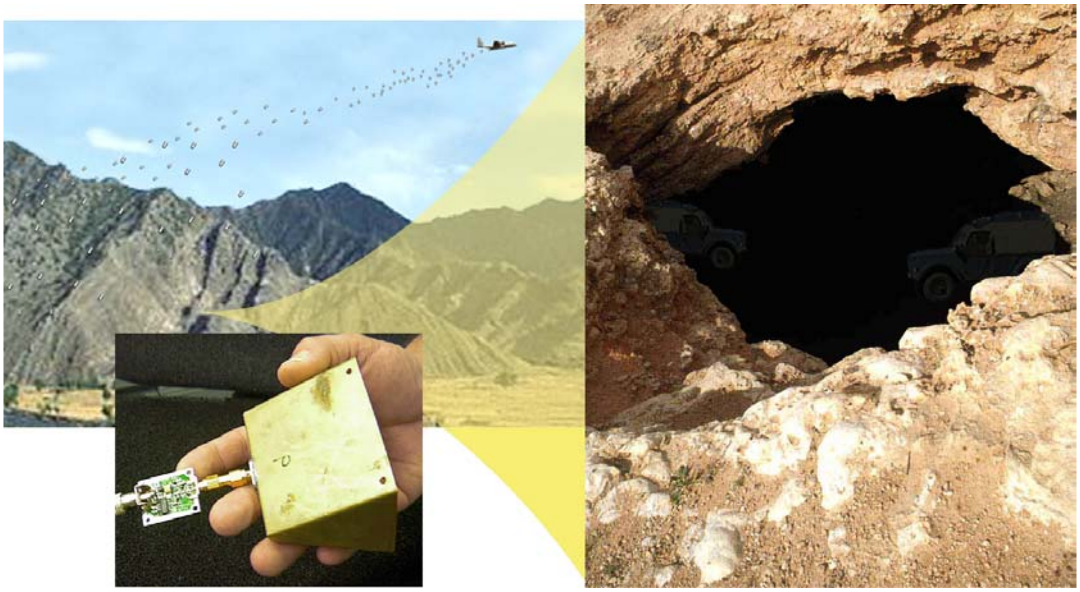
Multipath Fills In Shadowed Area



Sensor Technical Specifications

Max range	20 m	Beamwidth	90°, 120° or Omni
Min range	0.01 m	Antenna connector	SMA typ.
Range linearity	0.03% of full scale	Dynamic range	80dB
Range stability	0.1% of FS, -35° to +65°C	Video output	+/- 4Vpk
RF power	1mW, +0dBm	Output bandwidth	0.01 to 1 kHz
Duty cycle	0.4%	Power	3.2 Vdc, 8 mA max
RF pulse width	1-ns	PCB size / material	2.5 x 4.0", .062" FR-4
PRF	.1 - 5 MHz w/opt. dither	Interface connector	Mini-DB9, SMA, BNC...
Dither	0 - 300ns		

Bunker/Cave Monitoring Sensor Network



CAVE MONITORING SENSOR

Key Features

- Air-dropped or hand deployed
- Detects personnel/ vehicle motion
- Battery operated (6 days on 2 ea. AA batteries)
- Covert RF signal
- RF local-link or IR Sat-com link
- All weather day/ night operation

Description

The Bunker/Cave Monitoring Sensor Network is a battery operated radar sensor suitable for monitoring personnel and vehicle motion at or in caves. Sensor can be configured to relay detection information by RF local-link or IR sat-com link. Sensitive receiver detects very slow (0.1"/sec crawling) to very fast (40 mph) motion. Key fob operation available on custom unit. Optional indicator LED's report sensor status. Available only to US government agencies including DoD military. Unit transmits a low observable signal (one fiftieth cell phone signal strength) - difficult to detect. Procuring authority responsible for regulatory approvals.

	Size	Weight	Power
Cave Monitoring Sensor	2.4" x 2.4" x 2.4"	8 oz.	30mW

University of California
Lawrence Livermore National Laboratory

UCRL-PRES-146514

General Features

Two-Part Unit

Radar

- Human target
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Signal Output

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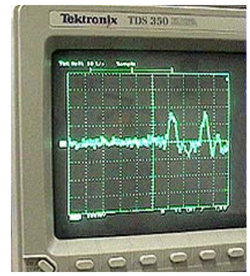
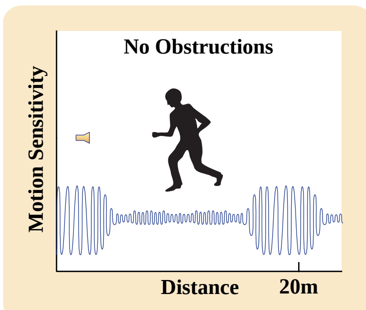
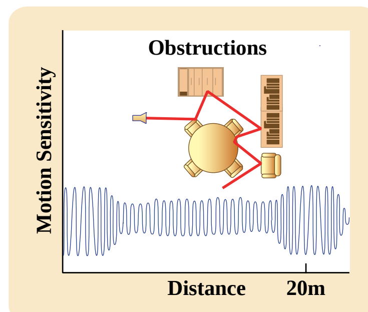
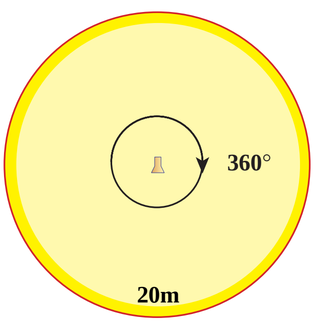


Typical Signal Output

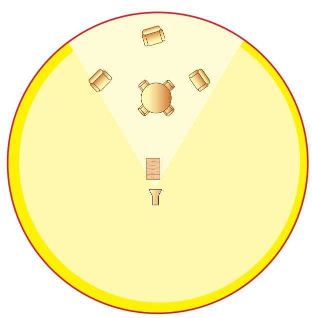
Typical Signal Output



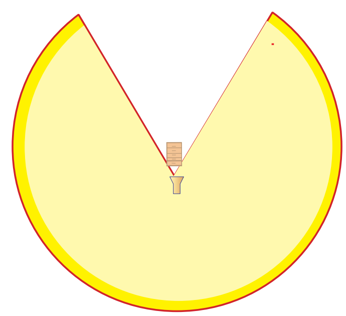




Multipath Fills In Shadowed Area



Signal Shadowed



Sensor Technical Specifications

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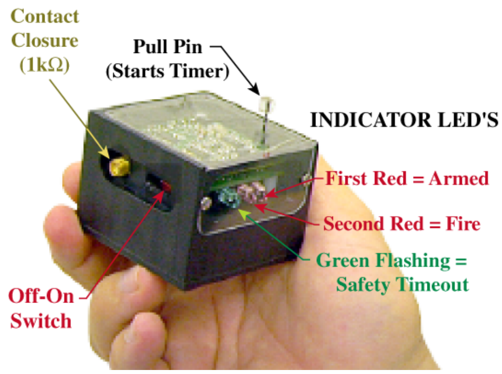
PRF	.1 - 5 MHz w/opt. dither	Interface connector	Mini-DB9, SMA, BNC...
Dither	0 - 300ns		

Electronic Tripwire



Key Features

- Invisible detection sphere (2 – 20 ft.)
- Triggers radio, camera or HE device (not included)
- Battery Operated (2 ea AA, 24 hr. continuous)
- Very low RF signature, virtually undetectable
- Simple LED display, low signature option

Description

The Electronic Tripwire sensor is a battery operated radar sensor capable of wirelessly detecting motion and reporting back to operator. Sensor suitable for use as an initiation device or with a transponder as a warning device. Sensitive receiver detects very slow (0.1"/sec crawling) to very fast (40 mph) motion. Pull pin to operate. Sensor times out after set time (8sec). Key fob operation available on custom unit. Indicator LED's report sensor status (Green = 8 second timer running, Red = armed). Available only to US government agencies including DoD military. Unit transmits a low observable signal (one fiftieth cell phone signal strength) - difficult to detect. Procuring authority responsible for regulatory approvals.

	Size	Weight	Distance
Electronic Tripwire Sensor	2.4" x 2.4" x 2.4"	8 oz.	2 ft.
Electronic Tripwire Sensor	2.4" x 2.4" x 2.4"	8 oz.	4 ft.
Electronic Tripwire Sensor	2.4" x 2.4" x 2.4"	8 oz.	8 ft.
Electronic Tripwire Sensor	2.4" x 2.4" x 2.4"	8 oz.	20 ft.

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ELECTRONIC TRIPWIRE

UCRL-PRES-146514

General Features

Two-Part Unit

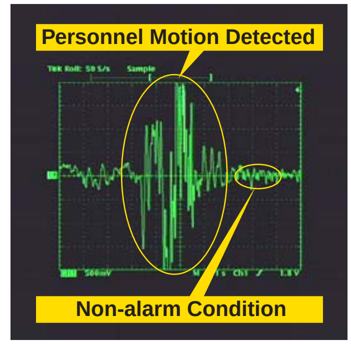
Radar

- Human target
- 0.6 mph max. speed
- 0.001 mph min. speed (crawl)
- Stealthy (low-signature) signal avail.
- 20 meter max. range
- Batteries, 2 ea. for 6-day operation

Portable Radar Unit

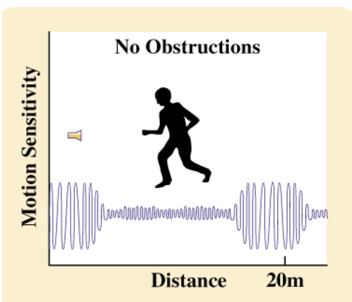
Signal Output

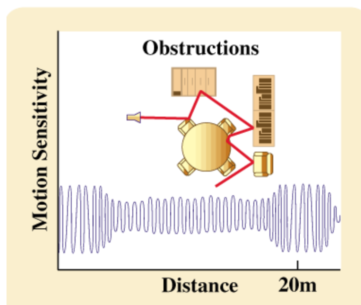
- Adjustable Sensitivity
- Reports to Radio Transmitter or other Indicator
- Key FOB Controlled

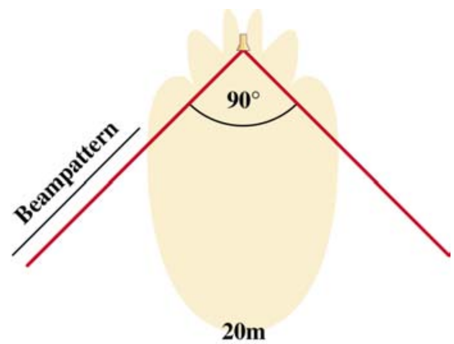


Typical Signal Output

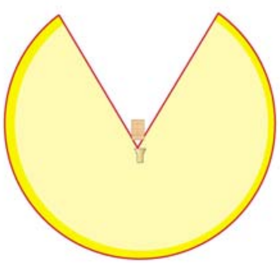
Typical Signal Output

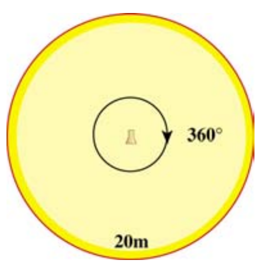




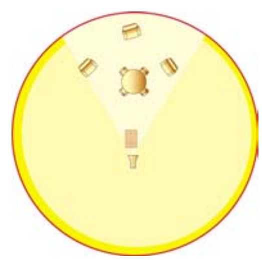


Signal Shadowed





Multipath Fills In Shadowed Area



Sensor Technical Specifications

Max range	20 m	Beamwidth	90°, 120° or Omni
Min range	0.01 m	Antenna connector	SMA typ.
Range linearity	0.03% of full scale	Dynamic range	80dB
Range stability	0.1% of FS, -35° to +65°C	Video output	+/- 4Vpk
RF power	1mW, +0dBm	Output bandwidth	1 kHz
Duty cycle	0.4%	Power	3.2 Vdc, 8 mA max
RF pulse width	1-ns	PCB size / material	2.5 x 4.0", .062" FR-4
PRF	.1 - 5 MHz w/opt. dither	Interface connector	Mini-DB9, SMA, BNC...
Dither	0 - 300ns		

Flashlight Sensor

Key Features

- Detects enemy movement (to 60 ft.)
- Penetrates foliage, wood, rock, concrete, (not metal)
- Battery Operated (AA, 6 days continuous)
- Very low RF signature, virtually undetectable
- Water resistant

Description

The flashlight sensor is a battery operated radar sensor suitable for use as a personnel detection device or warning device. Sensor is handheld, water resistant and looks like a flashlight. Sensor detects adversary motion through walls, doors, etc. Sensor will not penetrate solid metal. Sensitive receiver detects very slow (0.1"/sec crawling) to very fast (40 mph) motion. Available only to US government agencies including DoD military. Unit transmits a low observable signal (one fiftieth cell phone signal strength) - difficult to detect. User responsible for regulatory approvals.

	Size	Weight
Flashlight Sensor	2.6" x 5.6" dia.	8 oz. with batteries

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FLASHLIGHT SENSOR

General Features

Two-Part Unit

Radar

- Human target
- 60 mph max. speed
- 0.001 mph min. speed (crawl)
- Stealthy (low-signature) signal
- 20 meter max. range
- Batteries, 2 ea.

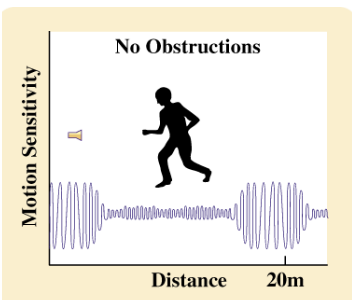
Portable Radar Unit

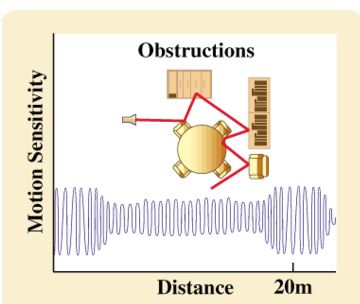
Display

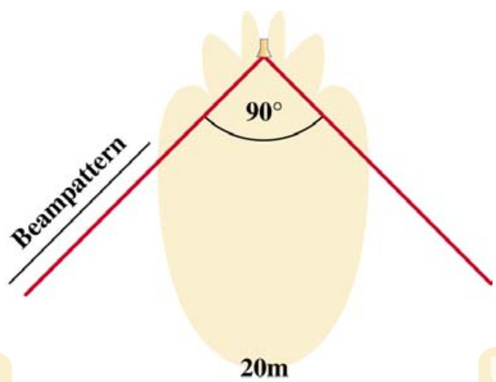
- 200 and 100 MHz bandwidth
- External trigger
- Roll mode
- Extra bright backlit display
- Advanced trigger - delay, pulse and video
- NiCd battery and AC adapter

Portable Radar Unit

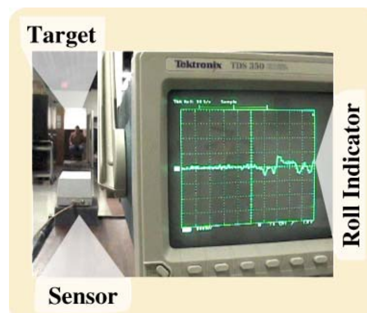
Sensitivity Curve (Typical)

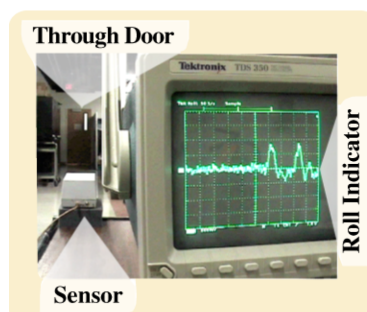






Breathing Detection





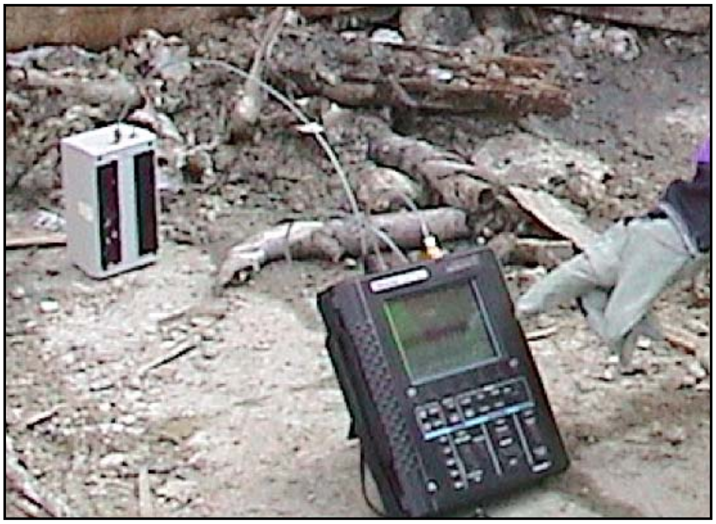
Sensor Technical Specifications

Max range	20 m	Beamwidth	90°, 120° or Omni
Min range	0.01 m	Antenna connector	SMA typ.
Range linearity	0.03% of full scale	Dynamic range	80dB
Range stability	0.1% of FS, -35° to +65°C	Video output	+/- 4Vpk
RF power	1mW, +0dBm	Output bandwidth	1 kHz
Duty cycle	0.4%	Power	3.2 Vdc, 8 mA max
RF pulse width	1-ns	PCB size / material	2.5 x 4.0", .062" FR-4
PRF	.1 - 5 MHz w/opt. dither	Interface connector	Mini-DB9, SMA, BNC...
Dither	0 - 300ns		

Human Presence Detector (Through-Wall)

Key Features

- Detects breathing (30 ft.)
- Battery Operated
- Covert RF signal
- Visual LCD display



Background

Livermore develops custom electronic sensor and radio systems based on short pulse technology. Development principle for all MIR systems: *"Small, light and inexpensive"*.

Description

The Human Presence Detector is a battery operated radar sensor suitable for use as an initiation device or with a transponder as a warning device. Sensitive receiver detects breathing through walls, doors, etc. This detector will not penetrate solid metal barriers. LCD displays breathing indicated on a rolling graphical output. Available only to US government agencies including DoD military. User responsible for regulatory approvals.

Future

While this sensor demonstrates revolutionary capability, the work is not done. System integration, software, human interface, testing and production quality assurance practice all must be performed so that this technology can be most effective.

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HUMAN PRESENCE DETECTOR

UCRL-PRES-146514

General Features
Two-Part Unit

Radar

- Human target
- 60 mph max. speed
- 0.001 mph min. speed (crawl)
- Stealthy (low-signature) signal
- 20 meter max. range
- Batteries, 2 ea.
- Size: 3" x 3" x 5"
- Weight: 6 oz.

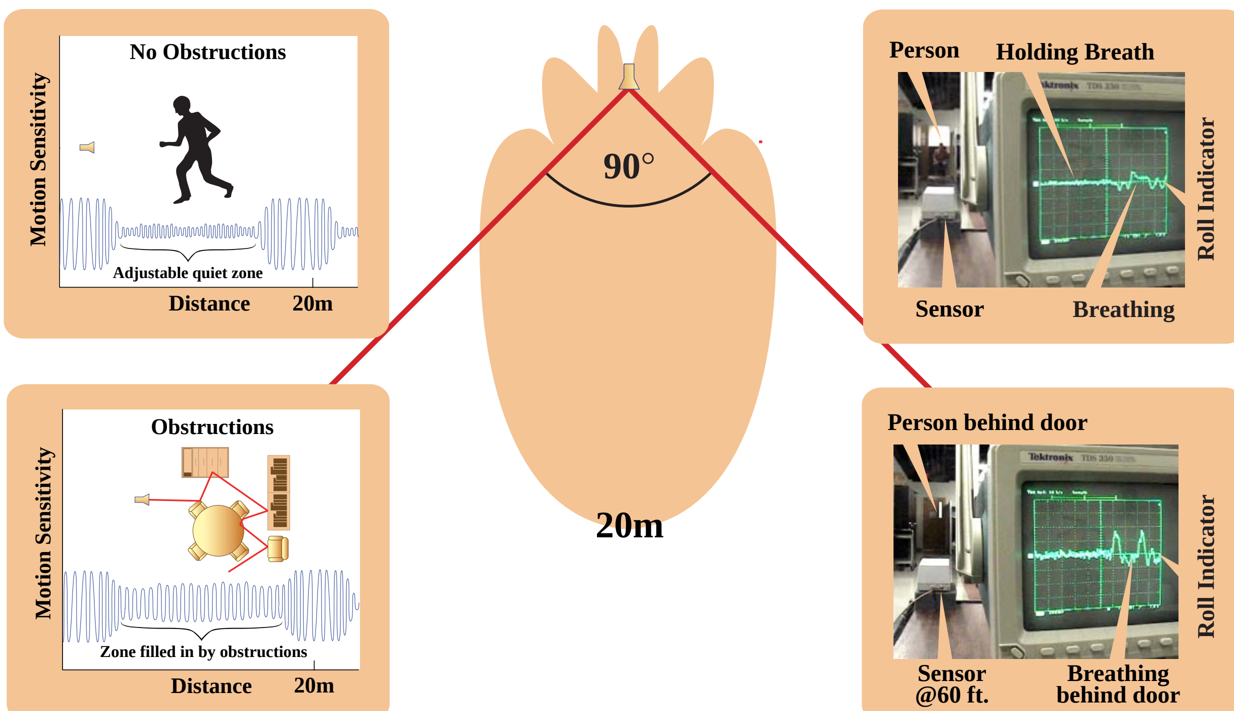
Portable Radar Unit

Display

- 200 and 100 MHz bandwidth
- External trigger
- Roll mode
- Extra bright backlit display
- Advanced trigger - delay, pulse and video
- NiCd battery and AC adapter
- Size: 2" x 8" x 11"
- Weight: 1.5 lb.

Portable Display Unit

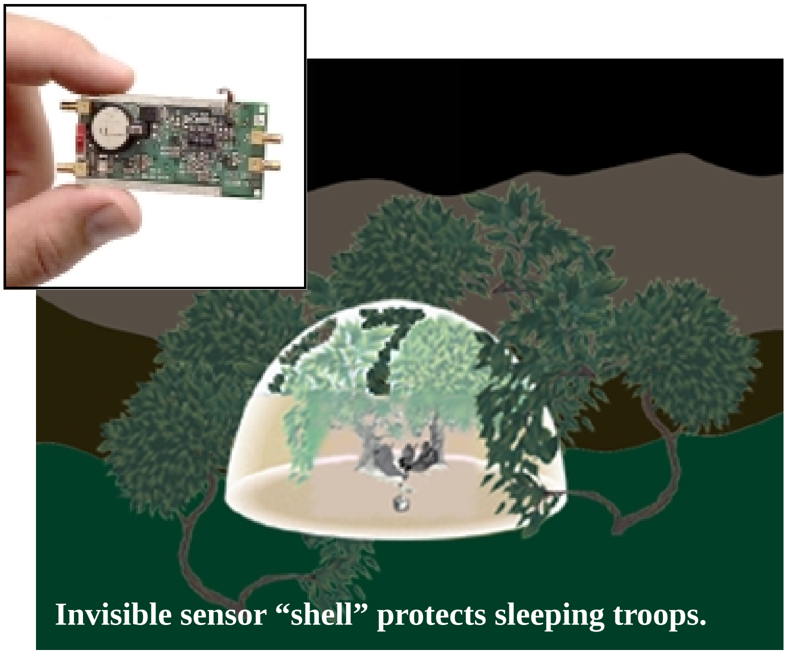
Sensitivity Curve (Typical) **Typical Beampattern** **Breathing Detection**



Sensor Technical Specifications

Max range	20 m	Beamwidth	90°, 120° or Omni
Min range	0.01 m	Antenna connector	SMA typ.
Range linearity	0.03% of full scale	Dynamic range	80dB
Range stability	0.1% of FS, -35° to +65°C	Video output	+/- 4Vpk
RF power	1mW, +0dBm	Output bandwidth	1 kHz
Duty cycle	0.4%	Power	3.2 Vdc, 8 mA max
RF pulse width	1-ns	PCB size / material	2.5 x 4.0", .062" FR-4
PRF	.1 - 5 MHz w/opt. dither	Interface connector	Mini-DB9, SMA, BNC...
Dither	0 - 300ns		

Perimeter Sensor



Invisible sensor “shell” protects sleeping troops.

Key Features

- Detects personnel/ vehicle motion
- Battery operated (6 days on 2 ea. AA batteries)
- Covert RF signal
- Visual LED display or earphone audio
- All weather day/ night operation

Description

The Perimeter Sensor is a battery operated radar sensor suitable for use as an intrusion sensor or with a transponer as a warning device. Sensitive receiver detects very slow (0.1”/ sec crawling) to very fast (40 mph) motion. Sensor can be air dropped or hand-placed and emits IR sat-comm link. Optional indicator LED’s report sensor status. Available only to US government agencies including DoD military. Unit transmits a low observable signal (one fiftieth cell phone signal strength) - difficult to detect. Procuring authority responsible for regulatory approvals.

	Size	Weight	Power
Perimeter Sensor	**2.4” x 2.4” x 2.4”**	**8 oz.**	**30mW**

PERIMETER SENSOR

University of California
Lawrence Livermore National Laboratory

Portal Sensor

What it does

- The Portal Sensor safely images people as they walk through.
- Detects metal, plastic, and ceramic objects larger than a quarter.
- Facial and personal features not recognizable (see image).
- 3-D, potentially real-time.

Accomplishments/Status

- LLNL has demonstrated feasibility with simple prototype:
  - — Single radar, mechanical scan
  - — Simple image formation/display
  - — Low speed
- LLNL's suite of hardware options, tunability, software, etc. gives flexibility depending on end-user application need.

Technology

- Uses proven low-power RF sensors and sub-systems developed at LLNL.
- Low-observable signal.
- Array imager.
- Safe—approximately 2% of a cell phone's energy.

Business Model/Opportunity

- LLNL willing to work with industrial partner to leverage LLNL technology to develop this system.
- Potential large and growing targeted applications:
  - — Airports
  - — Public buildings, events
  - — Private security

ENGINEERING

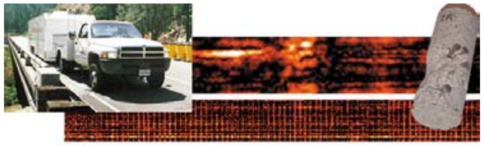
HERMES: A Bridge Inspection System

What it does

- HERMES provides 3D pictures of the interior of a bridge deck using radar imaging.
- HERMES GOAL: to provide a new method for bridge inspection to which is more effective, inexpensive, and timely than previous techniques.

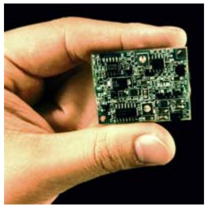
Accomplishments/Status

- HERMES-1: Delivered to FHWA 11/98
- HERMES-2: Funded by consortium of states:
  - Tech development FY01
  - Prototype development 2002-04
- Imaging experiments / analysis needed to characterize performance.



Technology

Micro Radar

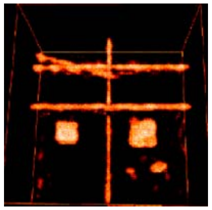


Small
Low-power
Ultra wideband

Antenna

Compact
Lightweight
Ultra wideband

Imaging



True 3D map
High resolution

Business Model/Opportunity

- Government funding expected to continue through completion of HERMES-2 prototype.
- Commercial partners being identified (both domestic and foreign).
- Business model / plan exists:
  - Manufacturing component
  - Services component
  - Significant business opportunity (over 600,000 bridges in U.S. alone)

ENGINEERING

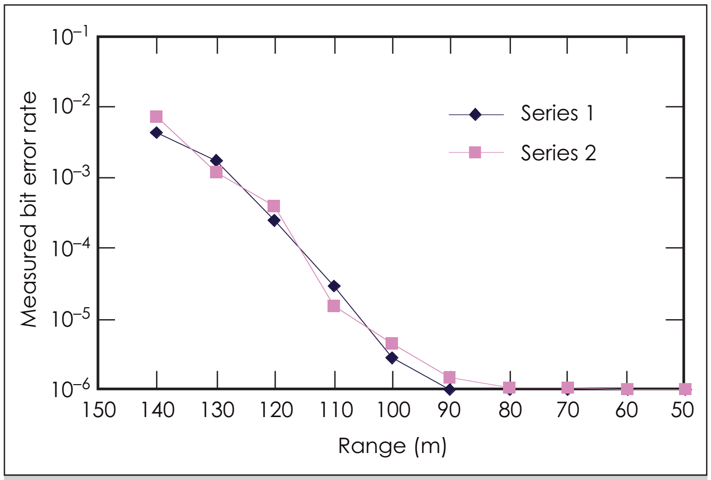
Ultrawideband communications

F. Dowla, A. Spiridon, D. Benzel, T. Rosenbury, S. Azevedo

In most intelligence applications, it is important to collect data rapidly and transmit it covertly and reliably. In these applications, robust, short-range, covert wireless communications systems are needed that have low probability of detection, low probability of intercept, and low-power, small-size sensor communication hardware that is suitable for both clandestine urban and battlefield operations. Commercial communication systems that operate in fixed frequency bands are easily detectable, prone to jamming by the enemy, and may lack the requisite robust communication links between the sensors collecting the data, a critical issue for demonstrating the real-time performance of a distributed sensor network.

Our goal in this project is to develop advanced ultrawideband (UWB) communication transceivers and radios that would fulfill these important needs of our country's defense and intelligence communities.

Our goal for FY2001 was to build a highly covert UWB radio with a data capacity of 200 kilobits per second (kbps) and a range of 100 m. With our first-generation transmitters, we were challenged to meet simultaneously the requirements for both data capacity and range. Although our initial design exceeded the data capacity by more than an order of magnitude (>2 Mbps)—the transmission range was limited to a few meters. However, we designed, implemented, simulated, and experimentally tested (with both data and voice communication) several prototype UWB radios that meet those requirements. As the Figure shows, in one variation of our design the radio transmitted up to a range of 110 m at 115 kbps with a bit error rate (BER) of better than 0.0001. For this test, the data capacity was limited by the capabilities of the laptop computer being used as part of the test equipment. Our new UWB waveform design permits data transmission at megabits per second.



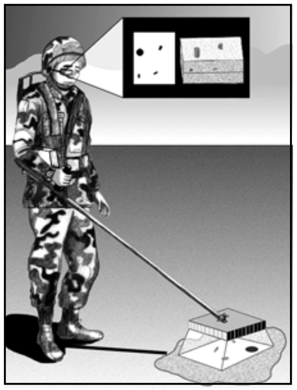
Performance of a prototype ultrawideband (UWB) radio being developed for covert operation. In both test series, the bit error rate and range met design goals. Series 1 represents the model; Series 2 represents the empirical results.

In another significant success during FY2001, we verified experimentally that our UWB communication system had an improved level of performance, with a lower BER in the presence of multipath signal propagation. Most communication systems have difficulties in the presence of the multipath signal distortion caused by obstacles and reflectors. We invented a highly robust algorithm that can compensate for channel distortions.

In FY2002, we plan to reach a number of significant milestones that include (1) developing a detailed architecture design of our UWB radio, (2) completing final reports on modeling and propagation, (3) demonstrating improved signal-processing techniques at the receiver, and (4) quantifying the level of covertness of UWB radios. We also plan to complete (1) three working units of UWB radios with a data capacity of 1 Mbps, a range of 250 m, and a requirement of less than 0.5 W for two channels; and (2) robust, handheld, voice-communication UWB radios.

LANDMARC Radar Mine Detection

What it does

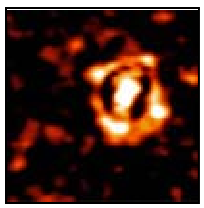


- LANDMARC is a system for 3-D imaging of buried landmines to allow safe removal.
- Could be hand-held, mobile, autonomous, multi-sensor.

Accomplishments/Status

- System concept and basic R&D completed.
- Simple prototype built and successfully tested at LLNL and at DoD test ranges.
- Prototype radars, antennas, signal processing and imaging software developed.

Technology



- Micropower Impulse Radar and/or related GPR radars at LLNL.
- Signal conditioning/processing and image formation software.

Business Model/Opportunity

- LLNL interested in variety of possible collaborations (CRADA, WFO, government funding, etc.).
- Industrial partner could simply license basic technology and pursue independently (not advisable).

ENGINEERING

Misc. Sensors

Smart Camera System

What it does

- The Smart Camera is a stand-alone digital video surveillance system using current computer microprocessor and LAN technology rather than the more traditional closed circuit television analog video technology.
- The imbedded microprocessor within the camera (sensor module) allows for automated scene analysis and alarm/notification level decision-making.

Accomplishments/Status

- The Smart Camera surveillance system was funded by DOE and developed for high-level weapons security applications within the National Laboratory complex.
- The initial Smart Camera design was completed in FY2000.
- Several prototypes were built in late FY2000 and are currently under going alpha testing and evaluations while additional system software enhancements are under development.

Technology

- Four patent applications cover the technology.
- The system APIs and application software can be copyrighted or patented.
- Secure & authenticated control and video data communications between camera and host computer forms robust tamper-proof system.
- The open system architecture coupled with a flexible feature interface allows for easily added new user applications or enhancements.

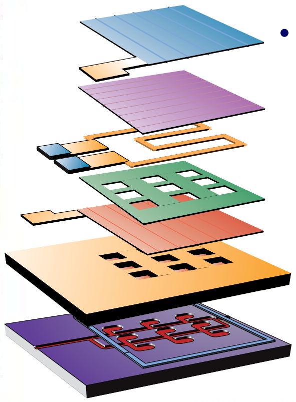
Business Model/Opportunity

- Continued DOE funding is expected for new system enhancements and upgrades.
- Industrial partners are being sought to commercialize the technology and make it available to the private sector.
- Technology licensing is available.
- Cooperative research and development (CRADA) and “work for hire” agreements are available to assist industrial partners.

ENGINEERING

MEMS-based Fuel Cells

What it does



- LLNL's MEMS-based fuel cell power sources are being developed as a replacement for conventional batteries. Direct methanol conversion proton exchange membrane (PEM) designs as well as solid oxide fuel cells (SOFC) are under development for numerous government and potential commercial applications.

Accomplishments/Status

- The MEMS-based fuel cell technology development was funded for several years by internal R&D funds as a potential power source for remote sensors, distributed sensor networks and other government applications.
- A proof of concept PEM design was completed and demonstrated in FY2001.
- A fully integrated pre-production prototype PEM fuel cell is expected to be available for demonstration in mid FY2002.

Technology

- Multiple patents and patent applications cover the LLNL MEMS-based solid oxide and proton exchange membrane fuel cell technology.

- A modular packaging assembly will allow the initial targeted power levels of $\leq$ 40 watts to be achieved through stacking the individual fuel cells.

Business Model/Opportunity

- DARPA funding is expected to continue in FY2002 plus internal R&D funds for the development of a catalytic micro-reactor for direct hydrogen generation.
- Industrial partners are being sought to further develop and commercialize the technology through "work for hire" agreements, Cooperative Research and Development Agreements (CRADA) and technology licensing.
- Possible commercial target market sectors include: cell phones, PDAs, laptop computers, etc.

ENGINEERING

Femtoscope: A Time Microscope Using Parametric Temporal Imaging

B. Kolner, C. Bennett

An interesting duality exists between the equations that describe the natural spreading of optical beams in space and the spreading of short pulses in space–time. The former is known as diffraction, and the latter as dispersion. Building on these analogies forms the basis of a technique that we call "temporal imaging," the time domain analog of a conventional spatial imaging system. With it, we recently demonstrated a hundredfold temporal magnification of subpicosecond optical waveforms.

The capability of generating optical pulses of less than 100 fs has become almost routine. The principles of generating, detecting, and characterizing these pulses underlie much of modern optical telecommunications and ultrafast science in general. For several years, we have been investigating the possibility of stretching out short optical waveforms to a time scale that is accessible to conventional instrumentation, such as digitizing or sampling oscilloscopes. The key feature of our approach is that the expanded waveform maintains the integrity of the original envelope profile. Just as conventional imaging devices, such as cameras and microscopes, maintain the relative brightness levels between specific regions of the object plane, the temporal image maintains the relative amplitude levels between different portions of the expanded waveform—hence the term "temporal image."

The principal components and operation of a time microscope are relatively straightforward. Dispersive networks, such as diffraction grating pairs or optical fibers, play the role of the free-space diffraction, like the object-to-lens or lens-to-image-plane distance in a camera. A quadratic time-phase modulator that we call the “time lens”plays the role of a conventional space lens. A time lens can be realized with an electro-optic phase modulator, but these only produce a weak phase modulation. What is needed is hundreds or thousands of radians of modulation. We have taken the approach of mixing the dispersed waveform with a linearly chirped pump in an up-conversion nonlinear mixing crystal. By combining the input and output dispersions with the proper amount of chirped pump, we satisfy the time-domain equivalent of the imaging condition, and waveforms can be magnified or demagnified according to the output-to-input dispersion ratio.

In our LDRD-funded proof-of-principle experiment, we set a goal of 100× magnification and 100-fs resolution. The experiment consisted of a mode-locked Ti:sapphire laser producing 100-fs pulses, adjustable diffraction-grating dispersive delay lines, and an interferometer for creating a two-pulse test pattern. We achieved 103× magnification, as verified on a high-speed sampling oscilloscope, and less than 200-fs resolution, which is consistent with theory. The temporal field of view was about 10 ps, yielding more than 50 resolvable points.

As is the case with its spatial counterpart, temporal imaging is subject to aberrations, which arise from the non-ideality of the dispersive delay lines and the time-lens phase function. We have made a detailed theoretical study of these effects and have measured them in our experimental setup. Although they impact the quality of the expanded waveform, we have found that the aberrations are almost insignificant on the time scales we are currently using. This is equivalent to using relatively high *f*-number optical systems where systematic aberrations are usually negligible.

Temporal imaging is very appealing because it is fundamentally a single-shot process, as we recently demonstrated with the aid of a streak camera. This feature, combined with subpicosecond resolution, makes the technique attractive as a high-power laser diagnostic. We expect that further development using compact-fiber Bragg gratings and integrated optical sum-frequency converters will produce a compact, high-performance optical waveform recording instrument with diverse applications in science and technology.

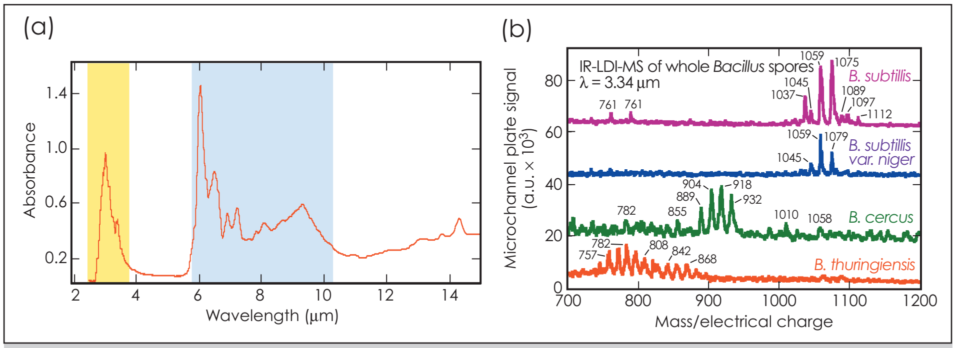
Real-time mass-spectrometric detection and identification of biological aerosols

K. Langry

Most techniques for pathogen detection, such as polymerase chain reaction (PCR), flow cytometry, and conventional mass spectrometry, require time-consuming sample preparation and complex reagents, and have slow response (time scale of minutes). The objective of this project was to demonstrate the feasibility of real-time aerosol analysis with a system that can detect and identify individual biological aerosol particles in milliseconds with no sample preparation and no reagents.

The bioaerosol analysis system we envision would operate by pulling aerosols directly from the atmosphere into a vacuum chamber where an intense infrared (IR) laser pulse would be delivered to each bioaerosol particle, disrupting it and yielding various molecular ions. The masses of these ions, determined by time-of flight mass spectrometry (TOF-MS), would be used to identify the microorganisms that constitute the particle.

An aerosol mass-spectrometry system would be ideally suited for autonomous, continuous, long-term operation at ground-based sites and aboard airborne sampling platforms. The system would significantly expand the capabilities for detection of biological agents in military and civilian applications.



(a) The infrared (IR) spectrum of *B. subtilis* spores exhibits two major absorption bands, one centered around 3.3 μm (yellow) and the other at 6.2 μm (blue). These two wavelengths are characterisitic of dipicolinic compounds that make up a large portion of *B. subtilis* spores. (b). A thin film of spores from four different *Bacillus* species were pulsed with a 3.34-μm IR laser beam and produced the unique time-of-flight mass spectra shown here.

The experimental approach taken in this project was first to demonstrate that molecular signatures of various common bacteria could be obtained from spores using the matrix-assisted laser desorption/ionization (MALDI) technique with TOF-MS. This was achieved in the first year of the project (FY1998) using UV-MALDI. During FY1999, we demonstrated that unique bacterial signatures can be obtained with matrix-free samples by TOF-MS using a pulsed IR laser.

In FY2000, we planned to demonstrate that with a pulsed IR laser we could disrupt aerosolized spores passing through the source of a TOF-MS and generate mass spectra unique to the bacteria from which they originated. The development of mass spectra from aerosolized biological material proved to be a technical challenge. It was also an administrative challenge, because of the necessity of developing a safe protocol for generating and analyzing biological aerosols. This was accomplished late in this final year of the project (FY2001) with approval of an Integrated Work Statement.

As protocols for handling and analyzing the aerosols were developed during FY2001, we addressed the technical challenge of interfacing the electronic timing circuits of the laser system with the mass spectrometer. We detected mass spectra from biological aerosol particles using a pulsed UV (266-nm) laser.

Our work in this project has established the feasibility of rapid identification of biological aerosols with IR laser desorption followed by time-of-flight mass spectroscopy (see Figure). Making real-time aerosol analysis work will depend on accurate timing of the firing of the IR desorption laser, which must take place within a window of less than 1 μs and with a timing that depends on particle mass. Just as critical will be accurately determining the timing of events leading up to laser firing (charging the capacitors that drive the Nd:YAG pump laser, thermally equilibrating the optical parametric oscillator crystal that delivers the IR pulse, and allowing for the recovery time of the laser rods). Once these timings are known, it should be possible to assemble and evaluate a prototype system.

Accelerator analyses for protein research

J. S. Vogel, P. G. Grant

Sequencing the human genome and discovering genes within that code are triumphs of modern technology in biological research. We know that (1) coded material is expressed as proteins to produce biochemical effects, (2) proteins are sequences of amino acids found either by high-resolution mass spectrometry (MS) or through improved chemical sequencing, and (3) linking proteins to their originating genes is straightforward. However, expression—or production—of a protein in a specific cell depends on many factors: other genes and cellular signals that trigger expression or control modification of the product. Advanced technology is required to study expressed proteins and their relation to cell dynamics and controlling processes.

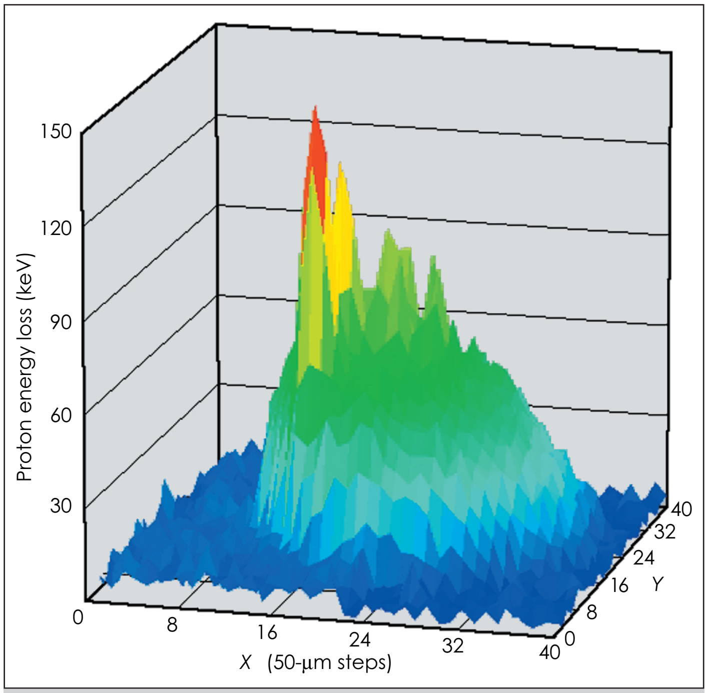
In this research, we are applying physical measurements of accelerated ions to the problem of precise protein quantitation, which avoids uncertainties resulting from the variable chemical properties of proteins. This project builds on the expertise within LLNL's Center for Accelerator Mass Spectrometry (CAMS) for applying nuclear technology to biological research to advance LLNL's biological sciences mission and strengthen our program in proteomics.

Improved quantitation of protein interactions is central to several areas of biological research at LLNL and at collaborating campuses of the University of California (UC). For example, because toxins and drugs take effects by producing or interacting with specific proteins, the potency of new drugs and the danger of toxic chemicals can be reliably estimated only by finding the amounts of proteins directly affected by these compounds. Similarly, understanding the virulence of pathogens in biological threats requires precise macromolecular quantitation.

Our approach uses two technologies to quantitate the protein in a sample while quantifying the elemental or isotopic markers of protein interaction: (1) quantitation of areal density with accelerated protons and (2) isotope dilution by accelerated mass spectrometry (AMS).

Accelerated protons pass through the protein and its thin supporting substrate. The amount of proton energy that is lost is a direct measure of the material in the path. In our technique, a proton beam scans the sample to measure the total mass. The protons also induce heavy elements within the protein to produce distinctive x rays, thereby quantifying the elemental abundance. Protein–metal affinities are measured directly with high precision.

By using AMS to quantify the ^{14}C incorporated into molecules as labels for tracing chemical interactions, compounds can be quantified to high precision with very low levels of radiocarbon. To find the mass of the protein that is binding the compound, material with distinctive carbon-13(^{13}C) signatures is added. By measuring both $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios, AMS provides direct quantitation of the interaction. We also combine the techniques by quantifying the protein by energy loss and then measuring its ^{14}C content by AMS.



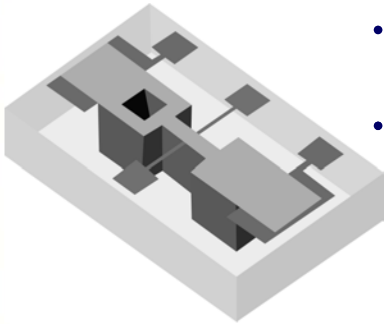
Proton energy-loss image of 1 µg of protein on 1000-Å film of silicon nitride at 50-µm resolution. Peak loss (red) is 160 ng of protein.

In FY2001, we surveyed substrates for uniformity of energy loss and found the best performance from silicon nitride wafers. These thin films give weight resolution of a few nanograms for protein samples,as seen in the Figure, where the transition from blue to green represents about 2 ng of protein for each pixel. The AMS equipment was modified to obtain ratio measurements with 0.3% resolution, sufficient for about 50-ng precision in quantifying micrograms of protein. In a refereed publication, we demonstrated our method's reproducibility in quantifying drug interactions with proteins separated by electrophoresis. We are investigating tube and flow-through electrophoresis to provide lower isotope contaminations and easier protein quantifications.

In FY2002, we will apply our proton-mass-measurement technique to quantification of elemental abundances within proteins from tumors, with the goal of characterizing how tumors differ from healthy tissue. To quantify protein affinity, we will apply isotope-dilution methods during measurements of protein binding to environmental chemicals.

MEMS based Accelerometers

What it does

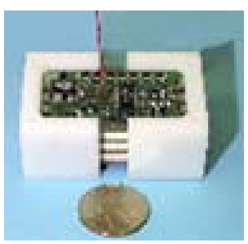


- Wireless MEMS based rocking accelerometer.
- As acceleration is applied, the proof mass tilts around the "tether"; thereby changing gaps in the sensing capacitor.
- Capacitive sensing has low power, high sensitivity, and wide temperature operating ranges.

Accomplishments/Status

- Prototypes exhibit low frequency (< 50 Hz), high sensitivity (microgauss), and uses minimal power.
- Has been packaged within a wireless sensor.
- Entire package for sensor, wireless electronics, and batteries fits in a cube 2 inch on a side.

Technology



- Sensitivity of accelerometers to low accelerations inversely proportional to size of mass, therefore need large mass to sense mg accelerations.
- Requires a thin (2µm) surface-micromachined tether that supports a large proof mass carved out of a bulk silicon wafer using Deep reactive-ion etching (DRIE).

Business Model/Opportunity

- Applications for Electronic Components, especially automotive, and industrial automation.
- Looking for R&D partners with expertise in wireless / sensor based platforms to further develop wireless network aspect of technology.
- Patent issued for technology.

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Magnetohydrodynamic Sensors

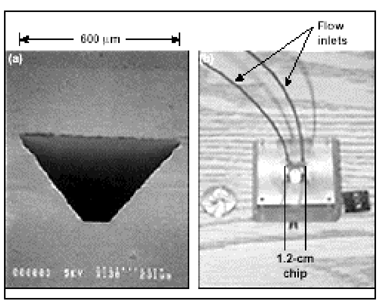
What it does

- MEMS based pump for microfluidic applications.
- No moving parts, minimal dead volume, and low power requirements.
- Can be used to accurate meter and mix volumes on a microfluidic level (e.g., picoliters).

Accomplishments/Status

- Fabricated and tested in glass and Silicon based systems.
- Used to mix and measure viscosity of fluids on a microfluidics level.

Technology



- Fluids are propelled through use of Lorentz force, i.e., charged particles moving in a uniform magnetic field feel a force perpendicular to both the motion and magnetic field.

Business Model/Opportunity

- Applications for Healthcare and environmental analysis, e.g. blood analysis and environmental sampling.
- Patents issued.
- Looking for R&D partners with strengths in diagnostic equipment and environmental analysis.

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